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NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

TECHNICAL NOTE

No. 1200

TENTATIVE TABLES FOR THE PROPERTIES
OF THE UPPER ATMOSPHERE

By Calvin N. Warfield

for the

NACA Special Subcommittee on the Upper Atmosphere

Langley Memorial Aeronautical Laboratory
Langley Field, Va.



Washington

January, 1947

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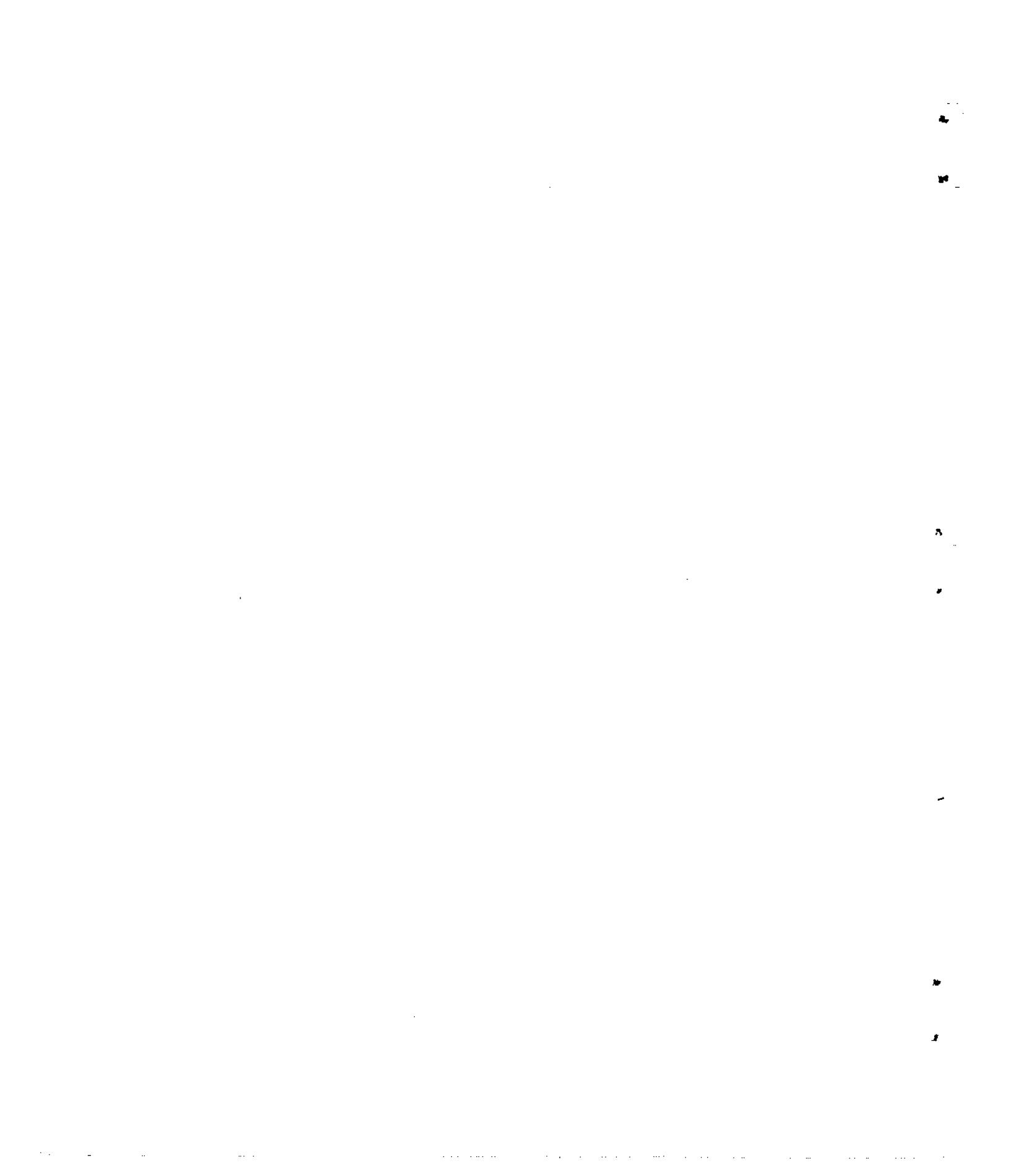
NACA Special Subcommittee on the Upper Atmosphere

SUMMARY

As a result of recent developments in aeronautics and ordnance, a need has arisen for tables of properties of the atmosphere at altitudes in excess of those covered by the existing standard tables (NACA Report No. 218). In order to satisfy this need, the National Advisory Committee for Aeronautics has adopted three temperature-height relationships and one composition-height relationship, and tables based upon them have been prepared for pertinent properties of the upper atmosphere (that is, from 20 to 120 kilometers in metric units, and from 65,000 to 393,700 feet in British units). In the absence of direct data, such as might be obtained by soundings with high-altitude rockets, the values adopted are based upon existing information obtained by indirect measurements of certain quantities. As a consequence, the tables are only tentative.

Two sets of tables based upon the adopted tentative standard specifications for the upper atmosphere are presented. One set of two tables is based upon the same arbitrary constant value for the acceleration of gravity as was used in the preparation of the existing standard tables for the lower levels (NACA Report No. 218). This set of tables for the upper levels of the atmosphere therefore constitutes a consistent extension of the existing standard tables. The other set of two tables takes into consideration the decrease in the acceleration of gravity with increasing altitude and therefore is more precise than the first set. Consequently, this set is presented only to satisfy the need for greater accuracy that may exist in some fields of research.

Each table is divided into separate parts for both day and night conditions at altitudes above 80 kilometers. The necessity for separate tables for day and night values is occasioned by the



In April 1946 this Panel was superseded by the Special Subcommittee on the Upper Atmosphere which was also appointed by the NACA.

The membership of this Special Subcommittee is as follows:

*Dr. Harry Hall - Navy E.E.T.
Dr. Joseph Kaplan, C.I.T.*

- Dr. Harry Wexler, U. S. Weather Bureau, Chairman
Col. D. N. Yates, Chief, Air Weather Service
Col. Paul H. Dane, A. C., TSEAC, AAF Air Materiel Command
Capt. H. T. Orville, USN, Office of Chief of Naval Operations,
Navy Department
Capt. Walter S. Diehl, USN, Bureau of Aeronautics, Navy
Department
^.-Dr. Calvin N. Warfield, Langley Memorial Aeronautical Laboratory
Dr. E. H. Krause, Naval Research Laboratory
Dr. W. G. Brombacher, National Bureau of Standards
Dr. L. V. Berkner, Carnegie Institution of Washington
Dr. B. Gutenberg, California Institute of Technology
Dr. Fred L. Whipple, Harvard Observatory, Harvard University
Dr. O. R. Wulf, Gates and Crellin Laboratories, California
Institute of Technology.
Mr. Jerome Teplitz, NACA, Secretary.

This Subcommittee has considered the information available concerning temperature and composition in the upper atmosphere. On the basis of existing data obtained by balloons at altitudes up to about 32 kilometers (references 6 and 7), of indirect measurements obtained at greater heights such as those discussed in references 8 to 14, and of unpublished data resulting from similar indirect measurements, recommendations concerning temperature-height and composition-height relationships were made by the Subcommittee on June 24, 1946. The recommendations regarding temperature-height relationships cover three arbitrary sets of temperature: (1) tentative standard temperatures, (2) probable minimum temperatures, and (3) probable maximum temperatures. Also, recommendation was made that at this time no tables be prepared for altitudes in excess of 120 kilometers because of the uncertainty regarding the validity of the data in this region.

At a meeting of the executive committee of the National Advisory Committee for Aeronautics held on August 15, 1946, the previously mentioned recommendations of the Subcommittee were adopted. As a result of the adoption of the recommendations of the Subcommittee, two sets of tables for the upper atmosphere, based upon the tentative standard temperatures, have been prepared at the Langley Laboratory of the NACA.

The first set of tables provides a consistent extension of the present standard tables for the lower levels of the atmosphere

(reference 1) because the same simplifying assumption of an arbitrary constant value for the acceleration of gravity is made in both cases. Because of this consistency with the present standard atmosphere tables, and in consideration of the fact that the present standard tables (reference 1) are widely used in evaluating performance characteristics of aircraft and for design purposes, it appears that this first set of tables may also be found useful in these same fields of aeronautical engineering. In addition, in order to be consistent with present practice in the use of the terms "pressure altitude" and "density altitude" (reference 15) it appears that it may be proper to use the term "tentative pressure altitude" to designate that altitude in this first set of tables which corresponds to a specified ambient-air pressure. Likewise, the term "tentative density altitude" can consistently be used with this set of tables in connection with ambient-air densities.

The second set of tables is more precise than the first because it takes into consideration the decrease in the acceleration of gravity with increasing altitude. This set is intended primarily for use in connection with research on the properties of the upper atmosphere. Values of still greater computational precision than those listed in this second set may be obtained by means of "latitude correction factors" which have been computed and tabulated in another table.

These two sets of tables for the upper atmosphere consist of two tables each, one in the metric system of units and the other in the British system of units. The altitude range covered is from 20 kilometers and 65,000 feet, respectively, to 120 kilometers and its British equivalent of about 393,700 feet. In addition to those quantities reported in references 1 to 5, there is included the mean free path of the air molecules. This quantity has been added because of its significance at high altitudes where the molecular mean free paths may be comparable to or larger than certain dimensions of the aircraft or missiles that may be flown there.

Acknowledgement is gratefully given for the contributions made by Dr. R. G. Stone, of the AAF Weather Service, who supplied valuable data concerning maximum and minimum temperatures over the entire world to altitudes of 32 kilometers, and for the thorough technical review and excellent suggestions offered by Mr. L. P. Harrison of the U. S. Weather Bureau.

SYMBOLS

a	speed of sound
c	most probable molecular speed
\bar{c}	average molecular speed
g	acceleration of gravity
h	altitude
K	volume gradient of oxygen dissociation $\left(\frac{\Delta v}{\Delta h} \right)$
L	temperature gradient $\left(\frac{\Delta T}{\Delta h} \right)$
M	molecular weight
m	mass of a molecule
N	number of molecules per unit volume
p	pressure
R	universal gas constant
r	radius of the earth
T	absolute temperature
t	temperature
v	volume of molecular oxygen in an initial unit volume of normal air, at the same temperature and pressure
w	specific weight (g_0)
γ	ratio of specific heats

- λ mean free path of molecules
 μ coefficient of viscosity
 ν kinematic viscosity (μ/ρ)
 ρ density (mass per unit volume)
 σ molecular diameter; also density ratio (ρ/ρ_0)
 $\bar{\sigma}$ average molecular diameter

The following subscripts are used to refer to the indicated conditions:

- 0 sea level
1 lower level
a top of region of dissociation, where oxygen is all atomic
A base of region with constant temperature and constant composition
B base of region with constant temperature gradient and constant composition
C base of region with constant temperature and constant volume gradient of dissociation
D base of region with constant temperature gradient and constant volume gradient of dissociation
g acceleration of gravity variable
m base of region of dissociation, where oxygen is all molecular
n nitrogen molecules
N non-oxygen (i. e., all constituents other than oxygen)
o oxygen
air mixture of molecules in atmosphere
 ϕ latitude

ADOPTED SPECIFICATIONS FOR THE UPPER ATMOSPHERE

Tentative Temperatures

Three sets of tentative temperature-height relationships have been adopted. One set gives tentative standard temperatures and the other two list values of the probable minimum and the probable maximum temperatures for the entire world. These three sets of temperatures which were originally recommended by the Subcommittee on the Upper Atmosphere are given by linear variations with altitude between the points specified in the following tabulation of temperatures.

TEMPERATURES

Altitude (km)	Probable minimum (°K) (a)	Tentative standard (°K)	Probable maximum (°K) (a)
0	225	b ₂₈₈	320
10.76923		b ₂₁₈	
11			250
17	180		
20		b ₂₁₈	
25			255
32		218	
45	200		380
50		350	
55	300		
60		350	
70			380
78		240	
80	170		300
83		240	
120	300	375	600

^aThe values of ambient air temperature listed in these two columns are not intended to represent extreme values for the entire world, and for all time, but rather values that bracket the temperatures over nearly all the earth most all the time.

^bThese values are standard, and have been used previously in references 1, 3, 4, and 5.

These temperature-altitude relationships are also shown in figure 1.

Tentative Composition

The tentative composition used in computing the tables was arrived at by taking into consideration the fact that, at altitudes below 80 kilometers in the day time and below 105 kilometers at night, the generally accepted variations in chemical composition are too small to affect appreciably the computed pressures and densities. However, it is believed that at levels above those just specified significant changes in composition result from the dissociation of oxygen molecules by solar radiation. It is furthermore known that the presence of water vapor in the atmosphere does not appreciably affect pressures and densities. As a result of such considerations, and in the interest of simplicity, the following tentative specifications for composition of the upper atmosphere were recommended by the Subcommittee and have been adopted for the purposes of computing the values in these tables:

(1) For day time, the dissociation of oxygen is such as to produce a linear volume gradient from all-molecular oxygen at 80 kilometers to all-atomic oxygen at 100 kilometers. Except for oxygen dissociation, the composition is the same as that at sea level.

(2) For night time, the dissociation of oxygen is such as to produce a linear volume gradient from all-molecular oxygen at 105 kilometers to all-atomic oxygen at 120 kilometers. Except for oxygen dissociation the composition is the same as that at sea level.

(3) At altitudes below the regions of oxygen dissociation the composition is the same as that at sea level.

(4) At altitudes above the regions in which both molecular and atomic oxygen exist, as stipulated in (1) and (2), and up to at least 120 kilometers, the composition is the same as that at sea level, except for oxygen which is in the atomic rather than in the molecular form.

The variation with altitude of the specified molecular oxygen content of the atmospheres is graphically portrayed in figure 2.

PHYSICAL RELATIONSHIPS

Basic Equations

In addition to the specifications for temperature and composition already listed, certain other assumptions are made and

serve as the basis for deriving the various equations used in computing the properties of the upper atmosphere. These additional assumptions are:

- (a) The air is dry
- (b) The air behaves as a perfect gas and hence obeys the general gas law which may be written

$$\frac{\rho}{\rho_0} = \frac{p}{p_0} \frac{T_0}{T} \frac{M}{M_0} \quad (1)$$

- (c) The air is at rest with respect to the earth and hence obeys the basic law for fluid statics

$$dp = -g_0 dh \quad (2)$$

By means of equations (1) and (2) and equations representing the adopted specifications for temperature and composition, relationships may be deduced between pressure and height. The equations representing the adopted specifications are

$$T = T_1 + L(h - h_1) \quad (3)$$

where L is the temperature gradient $\Delta T/\Delta h$, and

$$\frac{M}{M_0} = \frac{1}{1 - K(h - h_m)} \quad (4)$$

where K is the volume gradient of oxygen dissociation $\Delta v/\Delta h$. The derivation of equation (4) is given in appendix A.

In addition to the three assumptions just listed, it is necessary to make an assumption concerning the value of the acceleration of gravity. For the purpose of furnishing tables for the upper atmosphere that will be consistent with the present standard tables for the lower atmosphere (reference 1), it is necessary to make the same assumption concerning the acceleration of gravity as was used in preparing the standard tables. This assumption is

- (d) For the tables based on a constant value of g the acceleration of gravity at all altitudes is the standard sea-level value; that is,

$$g = g_0 \quad (5)$$

For those instances in which closer conformity to actual conditions is required than is inherent in these tables it is necessary to make another assumption concerning the value of the acceleration of gravity. This assumption is

- (e) For tables based on a variable value of g the acceleration of gravity varies inversely as the square of the distance from the center of the earth; that is,

$$g = g_0 \left(\frac{r}{r + h} \right)^2 \quad (6)$$

Pressure-Height Relationships

By use of the foregoing basic equations and assumptions, other equations are derived which relate pressure to altitude. Two sets of equations are used, one set based on a constant value of g as specified in assumption (d), the other set based on the variation of g that is specified in assumption (e). The deductions for the first set are indicated in appendix B and for the second set in appendix C. The equations that are based on a constant value of g are as follows:

For combination A (constant temperature and constant composition):

$$\log_e \left(\frac{p}{p_A} \right) = C_A (h - h_A) \quad (7)$$

where

$$C_A = - \frac{g_0 p_0 T_0}{P_0} \frac{M}{M_0} \quad (8)$$

For combination B (constant temperature gradient and constant composition):

$$\log \left(\frac{p}{p_B} \right) = C_B \log \left(\frac{T}{T_B} \right) \quad (9)$$

where

$$C_B = - \frac{g_0 p_0 T_0}{P_0 L} \frac{M}{M_0} \quad (10)$$

For combination C (constant temperature and constant volume gradient of dissociation) :

$$\log \left(\frac{p}{p_C} \right) = C_C \log \left(\frac{M}{M_C} \right) \quad (11)$$

where

$$C_C = - \frac{\varepsilon_0 \rho_0 T_0}{p_0 K} \quad (12)$$

For combination D (constant temperature gradient and constant volume gradient of dissociation) :

$$\log \left(\frac{p}{p_D} \right) = C_D \log \left(\frac{T}{T_D} \frac{M}{M_D} \right) \quad (13)$$

where

$$C_D = \frac{-\varepsilon_0 \rho_0 T_0 M_D}{p_0 (L M_0 + M_D T_D K)} \quad (14)$$

The equations derived in appendix C, based on a variable value of γ , are more complex than those listed in the foregoing and consequently they are not reproduced here.

Speed of Sound

The speed of sound at any altitude relative to that at sea level is computed by the equation

$$\frac{a}{a_0} = \left(\frac{\gamma T M_0}{\gamma_0 T_0 M} \right)^{1/2} \quad (15)$$

where the ratio of the specific heats γ , as derived in appendix A, is

$$\frac{\gamma}{\gamma_0} = 1 - \frac{128K(h - h_m)}{21M_0} \quad (16)$$

The variation with altitude of the ratio of specific heats γ for the specified atmosphere is shown in figure 3(a).

Coefficient of Viscosity

Sutherland's equation for the variation of the coefficient of viscosity with temperature is used. It is

$$\frac{\mu}{\mu_0} = \left(\frac{T}{T_0}\right)^{3/2} \left(\frac{T_0 + S}{T + S}\right) \quad (17)$$

in which, according to reference 16,

$$S = 120$$

when the T's are in °K, and

$$S = 216$$

when the T's are in °F absolute.

A caution concerning the use of values obtained from equation (17) for the upper atmosphere is given in the section entitled "Discussion of Tables."

Molecular Mean Free Path

The ratio of the molecular mean free path at any altitude to the corresponding value at sea level is computed by

$$\frac{\lambda}{\lambda_0} = \frac{p_0 T_0}{p T_0 g_0} \quad (18)$$

This equation is justified in appendix D.

BASIC CONSTANTS

In the preceding section equations are given by means of which several properties of the upper atmosphere are computed. These computations involve numerical values of the several properties at sea level. Appendix E discusses the chosen sea-level values for

each of several properties of the atmosphere and they are listed in table I in both metric and British engineering systems of units. Values are listed for each of the three specified atmospheres and in some instances the quantity is expressed in more than one unit in either the metric or British system.

The values listed in table I for the standard atmosphere at sea level are identical with those used in references 1 and 5 except in a few instances. The exceptions are noted and explained in appendix E.

DISCUSSION OF TABLES

The appropriate equation (equation (7), (9), (11) or (13) for the constant value of g , or (C3), (C6), (C10) or (C13) for the variable values of g) is used to compute the ratio of the pressure p at any height to the pressure at the base of the region to which that particular equation applies. These pressure ratios for each of the regions are then used to compute the ratio of the pressure p to the pressure p_0 at sea level. These ratios p/p_0 are given in tables II to V.

By use of the computed values of the pressure ratios p/p_0 and of the sea-level value of pressure p_0 as given in table I, the value of the pressure p is computed and then given in tables II to V. The pressures given in tables IV and V are also plotted against altitude in figure 3(b).

The remaining quantities given in tables II to V are similarly computed by means of the appropriate equation and the corresponding sea-level value given in table I. The values for these remaining quantities given in tables IV and V are also shown plotted against altitude in figures 3(c) to 3(h).

Attention is directed to the fact that all tables in this report are based on the engineering system (sometimes referred to as the gravitational system) in which the fundamental quantities are length, force, and time. The standard units for force used herein are, therefore, pounds for the British system and kilograms for the metric system.

Accuracy of Computed Tables II to V

In tables II to V all quantities except the mean free paths of the molecules are tabulated to four significant figures, and the mean free paths of the molecules are tabulated to three significant figures. All computations for table II were carried through to six significant figures and consequently the values given in this table are believed to be exact.

Most of the values for table IV were obtained from table II by use of suitable conversion factors evaluated by a graphical method described in appendix C. The errors resulting from the method, and therefore the errors in the values tabulated in table IV are believed not to exceed 0.01 of 1 percent.

A method of graphical interpolation was applied to obtain from tables II and IV the values for use at the intermediate levels tabulated in tables III and V. The accuracy of this method is such as to introduce an error of not over one-twentieth of 1 percent in the values listed in tables III and V. Consequently, whenever a discrepancy exists between the metric and British values, the metric values should govern.

Validity of Tabulated Values at the Higher Altitudes

Pressure, density, specific weight, and mean free path of molecules. - As was previously mentioned, the computations for tables II and III are based on a constant value for the acceleration of gravity g so that the values listed would be consistent with those appearing in the present standard tables for the lower levels of the atmosphere (reference 1). The errors in the computed values of pressure, density, specific weight and mean free path inherent in the assumption of a constant value for the acceleration of gravity become progressively greater with increasing altitude, being about 30 percent at 120 kilometers. However, a variation of 30 percent in pressure at 120 kilometers corresponds to a variation of less than 4 percent in altitude at this level, and at lower levels the change in altitude corresponding to the error in pressure rapidly approaches zero. It is apparent therefore that in at least some applications the values in tables II and III will be adequate and therefore useful. Furthermore, they represent an extension of the present standard tables (reference 1).

In order to satisfy the need that may exist for values that are not affected by the use of a constant value for the acceleration of gravity g , tables IV and V are presented. In these tables g is assumed to vary inversely as the square of the

distance from the center of the earth. This assumption therefore takes into consideration the variation due to gravitational attraction, but it does not allow for the effect of centrifugal force. The centrifugal force due to the rotation of the earth is known to be only a small fraction of 1 percent of the gravitational force at an altitude of 120 kilometers, and consequently this omission does not result in a significant error.

The standard value used for the acceleration of gravity at sea level (and at all altitudes for tables II and III) is 9.80665 meters per second per second. This value corresponds rather closely to the true acceleration of gravity at sea level at latitude 45°. (More specifically, it corresponds to the theoretical acceleration of gravity at sea level and at latitude 45° 24' according to the International formula. See reference 17.) If still greater accuracy than is inherent in tables IV and V is required at latitudes far displaced from latitude 45°, an estimate of the latitude effect upon pressure and density may be obtained by use of the equation

$$\log \frac{p_\phi}{p_0} = \frac{g_{0\phi}}{g_0} \log \frac{p}{p_0} \quad (19)$$

where p_ϕ is the pressure at altitude h and at latitude ϕ , and $g_{0\phi}$ is the acceleration of gravity at sea level and at latitude ϕ . A similar equation (replacing p 's with ρ 's) applies to densities.

By means of equation (19) it can be shown that a latitude correction factor (L.C.F.) defined by

$$\text{L.C.F.} = \frac{p_\phi}{p} \quad (20)$$

can be computed by

$$\text{L.C.F.} = \left(\frac{p}{p_0} \right)^{\frac{g_{0\phi} - g_0}{g_0}} \quad (21)$$

If values of $g_{0\phi}$ from reference 17 are used, the following values for the exponent $(g_{0\phi} - g_0)/g_0$ are obtained:

Latitude (deg)	$\frac{g_{0\phi} - g_0}{g_0}$	Latitude (deg)	$\frac{g_{0\phi} - g_0}{g_0}$
0	-2.66758×10^{-3}	50	0.42175×10^{-3}
10	-2.50922	60	1.28372
20	-2.05299	70	1.98732
30	-1.35337	80	2.44701
40	-0.49405	90	2.60670

The foregoing exponents when applied to the values of pressure ratio p/p_0 tabulated in tables IV and V give the values of the latitude correction factor described by equations (20) and (21). For latitudes at increments of 10° and for altitudes at increments of 10 kilometers the latitude correction factors that are applicable to the pressures given in tables IV and V have been computed and are presented in table VI. By means of table VI it is therefore possible to obtain computed values of pressure which take into consideration the variation with latitude of the sea-level value of the acceleration of gravity g_0 . This computation may be made by use of equation (20) which may be written $p_\phi = (L.C.F.)p$.

Coefficient of viscosity and kinematic viscosity. - The Sutherland formula (equation (17)) is strictly applicable only to a gas of constant composition and to pressures which are not too small, and consequently the tabulated values for the coefficient of viscosity and for the kinematic viscosity are obviously not entirely reliable at the higher altitudes. However, the lack of data on the viscosity of oxygen in the atomic form does not permit at this time an estimation of the correction that is needed to allow for the specified dissociation. Furthermore, because of the fact that the effective value of the viscosity of a gas at very low pressure flowing over a body depends on the size and shape of the body, it is not practical to give a correction that will be applicable to more than one specific size and shape of a body. The values for viscosity at the higher altitudes should therefore be used with caution.

Speed of sound. - The tabulated values for the speed of sound are believed to be correct for all altitudes covered by the tables.

Caution should be exercised, however, in using the tabulated values for the upper altitudes in connection with Mach numbers because at high altitudes where the mean free paths of the air molecules are large in comparison with the dimensions of the body moving through them, the laws of fluid dynamics do not apply and the laws of particle dynamics must be used. When aerodynamic forces, for example, are computed for these conditions by use of the laws of particle dynamics the most probable speed of the air molecules is found to be the basic quantity rather than the speed of sound.

As in the case of viscosity, the altitude range in which the most probable speed of the air molecules replaces the speed of sound as the basic quantity depends upon the size of the body under consideration. It is consequently not possible to specify a single level at which the molecular speed becomes significant in aerodynamics. For this reason values for the speed of sound are listed to 120 kilometers.

In any case in which the most probable speed of the air molecules c is needed rather than the velocity of sound a it is possible to obtain the value of c from the value of a listed in the tables by use of the appropriate factor obtained from the following tabulation:

Altitude, h		Ratio of the most probable molecular speed to the speed of sound, $\frac{c}{a} = \sqrt{\frac{2}{\gamma}}$	
(m)	(ft)	Day	Night
80,000	262,467	1.195	1.195
85,000	278,871	1.189	1.195
90,000	295,275	1.183	1.195
95,000	311,679	1.176	1.195
100,000	328,083	1.170	1.195
105,000	344,487	1.170	1.195
110,000	360,892	1.170	1.187
115,000	377,296	1.170	1.179
120,000	393,700	1.170	1.170

CONCLUDING REMARKS

The fact should be emphasized that the values given in the tables for the upper atmosphere are only tentative and as such may become obsolete after a sufficient number of reliable direct

measurements of certain quantities have been made available. In the meantime these tentative tables should be useful not only in serving as a basis for comparing performance characteristics and estimating limiting values of performance, but also in securing the additional data needed for revising these tentative tables for the upper atmosphere.

Langley Memorial Aeronautical Laboratory
National Advisory Committee for Aeronautics
Langley Field, Va., December 6, 1946

APPENDIX A

VARIATION WITH ALTITUDE OF MOLECULAR WEIGHT

AND RATIO OF SPECIFIC HEATS

Molecular Weight in the Region of Oxygen Dissociation

Consider an initial unit volume of normal air composed only of molecular gases, consisting of oxygen and other constituents. Let all the non-oxygen constituents be diatomic of average molecular weight M_N , and let the molecular weight of oxygen in the molecular form be M_m , and in the atomic form M_a . Then

$$M_a = \frac{1}{2} M_m \quad (A1)$$

Let the initial conditions be as follows:

v_0 volume of all-molecular oxygen at height h_m

$1 - v_0$ volume of non-oxygen components at height h_m

M_0 average molecular weight of the initial air mixture at height h_m

Then

$$M_0 = v_0 M_m + (1 - v_0) M_N \quad (A2)$$

At height h , between h_m and h_a (where h_m is height at base of region in which dissociation occurs, and h_a is height at top of the region, and where all the oxygen is in the atomic form) the volume of molecular oxygen v_m per unit initial volume of normal air is

$$v_m = v_0 \left(\frac{h_a - h}{h_a - h_m} \right) \quad (A3)$$

and the volume of atomic oxygen v_a per unit initial volume of normal air is

$$v_a = 2v_0 \left(\frac{h - h_m}{h_a - h_m} \right) \quad (A4)$$

Therefore, the average molecular weight M of the atmosphere at height h can be shown to be

$$M = \frac{M_0}{1 - K(h - h_m)} \quad (A5)$$

where

$$K = -\frac{v_0}{h_a - h_m} \quad (A6)$$

the volume gradient of molecular oxygen, $\Delta v/\Delta h$.

Ratio of Specific Heats in the Region of Oxygen Dissociation

The ratio of specific heats γ for diatomic gases is taken to be $7/5$ and for monatomic gases, $5/3$. If the ratio of the specific heats γ for the atmosphere is assumed to be given by a weighted average, according to relative masses, of the values of γ for diatomic and monatomic gases, it can be shown, by using equations (A1), (A2), (A3), and (A4) that for those regions of the atmosphere in which dissociation of oxygen occurs

$$\gamma = \frac{7}{5} + \frac{4}{15} v_0 \left(\frac{M_m}{M_0} \right) \left(\frac{h - h_m}{h_a - h_m} \right) \quad (A7)$$

The standard value for v_0 , for the atmosphere at sea level, is $7/5$, and for M_m the standard value is 32 . Therefore

$$\frac{\gamma}{v_0} = 1 - \frac{128K(h - h_m)}{21M_0} \quad (A8)$$

It is estimated that in the tentative standard atmosphere the variation of γ due to pressure and temperature effects is only about 0.6 of 1 percent. For this reason the effect of pressure and temperature upon γ is ignored in computing these tentative tables.

APPENDIX B

VARIATION OF PRESSURE WITH ALTITUDE (ASSUMING THE
ACCELERATION OF GRAVITY IS A CONSTANT g_0)

The equations relating atmospheric pressure to height for all altitude ranges in all three atmospheres (minimum, standard, and maximum temperatures) are only four in number. These four equations represent all possible combinations of the two types of temperature-height relationship and the two types of composition-height relationship. The deductions of the equations are based upon the familiar hydrostatic relation

$$dp = - g_0 \rho dh \quad (B1)$$

and upon the general gas equation

$$\frac{\rho}{\rho_0} = \frac{p}{p_0} \frac{M}{M_0} \frac{T_0}{T} \quad (B2)$$

These two equations, when combined, give

$$\frac{dp}{p} = - \frac{g_0 \rho_0 T_0 M}{p_0 T M_0} dh \quad (B3)$$

The differential equation (B3) is then used for deriving algebraic equations for pressure as a function of altitude, for each of the four combinations of temperature-height and composition-height relationships previously discussed. The derivations are indicated in the following paragraphs and the resulting equations are used in the preparation of tables II and III.

Combination A (constant temperature and constant composition). -- The type of atmosphere in which both the temperature and composition are constant may be represented algebraically by

$$T = \text{Constant}$$

and

$$M = \text{Constant}$$

Equation (B3) when integrated between the limits of height h_A and height h then becomes..

$$\log_e \left(\frac{p}{p_A} \right) = - \frac{g_0 \rho_0 T_0 M}{p_0 T M_0} (h - h_A) \quad (B4)$$

where h_A is the base of the region in which type A conditions prevail.

Combination B (constant temperature gradient and constant composition). - For the type of atmosphere having a constant temperature gradient and constant composition, let the temperature gradient be represented by

$$L = \text{Constant} = \frac{\Delta T}{\Delta h} \quad (B5)$$

and the temperature by

$$T = T_B + L(h - h_B) \quad (B6)$$

where T_B and h_B are the respective values at the base of the region to which combination B conditions prevail. Also $M = \text{Constant}$. Equation (B3) then becomes

$$\frac{dp}{p} = \left(- \frac{g_0 \rho_0 T_0 M}{p_0 M_0} \right) \frac{dh}{T_B + L(h - h_B)} \quad (B7)$$

and when integrated between the limits of h_B and h this equation becomes

$$\log \left(\frac{p}{p_B} \right) = - \frac{g_0 \rho_0 T_0 M}{p_0 M_0} \log \left(\frac{T}{T_B} \right) \quad (B8)$$

Combination C (constant temperature and constant volume gradient of dissociation). - In the type of atmosphere where both the temperature and volume gradient of dissociation are constant

$$T = \text{Constant}$$

and an expression for M as a function of h is derived in appendix A, and it is found to be

$$M = \frac{M_0}{1 - K(h - h_m)} \quad (B9)$$

where K is the volume gradient of molecular oxygen defined by

$$K = \frac{\Delta v}{\Delta h} = \text{Constant} \quad (B10)$$

Using these relationships with equation (B3) gives

$$\frac{dp}{p} = - \frac{s_0 p_0 T_0 dh}{p_0 T [1 - K(h - h_m)]} \quad (B11)$$

Integrating equation (B11) between the limits of h_C and h , where h_C is the height at the base of the region in which type C conditions prevail, gives

$$\log \left(\frac{p}{p_C} \right) = \frac{s_0 p_0 T_0}{p_0 T K} \log \left(\frac{M_C}{M} \right) \quad (B12)$$

Combination D (constant temperature gradient and constant volume gradient of dissociation). - The type of atmosphere having both the temperature gradient and the volume gradient of dissociation constant is referred to as combination D. For this combination, the expression for molecular weight given in equation (B9) and an appropriate modification of equation (B6) give, for equation (B3), the following equation:

$$\frac{dp}{p} = - \frac{s_0 p_0 T_0 dh}{p_0 [1 - K(h - h_m)] [T_D + L(h - h_D)]} \quad (B13)$$

Integrating the variable part of the right-hand member, between the limits of h_D and h , gives

$$\frac{1}{(1 + Kh_m)L + (T_D - Lh_D)K} \log \left[\frac{T_D + L(h - h_D)}{1 - K(h - h_m)} \right] \Bigg|_{h_D}^h$$

Therefore

$$\log \left(\frac{p}{p_D} \right) = \frac{-g_0 \rho_0 T_0 M_D}{p_0 (M_0 L + M_D K T_D)} \log \left(\frac{T_m}{T_D M_D} \right) \quad (B14)$$

APPENDIX C

VARIATION OF PRESSURE WITH ALTITUDE (ASSUMING THE ACCELERATION
OF GRAVITY VARIES INVERSELY AS THE SQUARE OF THE
DISTANCE FROM THE CENTER OF THE EARTH)

The equations relating pressure and altitude derived herein are based upon the general differential equation derived from equation (B2) of appendix B, from the hydrostatic relation

$$dp = -gp dh \quad (C1)$$

and from the equation representing the inverse square variation of the acceleration of gravity

$$g = g_0 \left(\frac{r}{r+h} \right)^2 \quad (C2)$$

This general differential equation is

$$\frac{dp}{p} = \frac{-g_0 p_0 T_0 M r^2 dh}{p_0 T_0 M_0 (r+h)^2} \quad (C3)$$

As in appendix B four equations are deduced for use in each of the four possible combinations of specified temperature-altitude and composition-altitude relationships. The resulting algebraic equations are used in the preparation of tables IV and V. The deductions for each combination are indicated in the following paragraphs.

Combination A (constant temperature and constant composition).

For combination A (constant temperature and constant pressure) the algebraic equation relating pressure and altitude is obtained by integrating equation (C3) between the limits of altitude h_A and h . The result is

$$\log_e \left(\frac{p}{p_A} \right)_g = \frac{-g_0 p_0 T_0 M}{p_0 T_0 M_0} \frac{r^2 (h - h_A)}{(r + h)(r + h_A)} \quad (C4)$$

(Note that in this equation and succeeding equations the subscript g is used to indicate values computed with the variation in the acceleration of gravity that is specified by equation (C2).)

Combination B (constant temperature gradient and constant composition). - For combination B (constant temperature gradient and constant composition) the differential equation is obtained by substituting in equation (C3) the value for T given by

$$T = T_B + L(h - h_B) \quad (C5)$$

The differential equation is then

$$\frac{dp}{p} = \frac{-g_0 p_0 T_0 M r^2 dh}{p_0 M_0 [T_B + L(h - h_B)] (r + h)^2} \quad (C6)$$

The algebraic equation obtained by integrating equation (C6) between the appropriate limits is

$$\log_e \left(\frac{p}{p_B} \right)_g = C_{B_g} \left[\frac{r(h - h_B)}{(r + h)(r + h_B)} + \frac{rL}{rL + h_B L - T_B} \log_e \frac{(r + h)T_B}{(r + h_B)T} \right] \quad (C7)$$

where

$$C_{B_g} = \frac{g_0 p_0 T_0 M}{p_0 M_0 \left[L - \frac{1}{r}(T_B - Lh_B) \right]} \quad (C8)$$

Combination C (constant temperature and constant volume gradient of dissociation). - For combination C (constant temperature and constant volume gradient of dissociation) the differential equation is obtained by substituting in equation (C3) the value of M given by

$$M = \frac{M_0}{1 - K(h - h_m)} \quad (C9)$$

The differential equation is then

$$\frac{dp}{p} = \frac{-g_0 p_0 T_0 r^2 dh}{p_0 T [1 - K(h - h_m)] (r + h)^2} \quad (C10)$$

The algebraic equation obtained by integrating equation (C10) between appropriate limits is

$$\log_e \left(\frac{p}{p_C} \right)_g = C_{Cg} \left\{ \left[\frac{\frac{K}{1 + Kh_C}}{K + \frac{1 + Kh_C}{r}} \log_e \frac{M(r + h)}{M_0(r + h_C)} \right] - \frac{r(h_C - h)}{(r + h)(r + h_C)} \right\} \quad (C11)$$

where

$$C_{Cg} = \frac{-g_0 p_0 T_0}{p_0 T \left(K + \frac{1 + Kh_C}{r} \right)} \quad (C12)$$

Combination D (constant temperature gradient and constant volume gradient of dissociation). - For combination D (constant temperature gradient and constant volume gradient of dissociation) the differential equation is obtained by substituting in equation (C3) the values of T and M given by a slightly modified form of equation (C5) and by equation (C9), respectively. The resulting differential equation is then

$$\frac{dp}{p} = \frac{-g_0 p_0 T_0 r^2 dh}{p_0 [T_D + L(h - h_D)] [1 - K(h - h_m)] (r + h)^2} \quad (C13)$$

The algebraic equation obtained by integrating equation (C13) between appropriate limits is

$$\begin{aligned} \log_e \left(\frac{p}{p_D} \right)_g &= C_{Dg} \left[\frac{a(h - h_D)}{(1 + xh)(1 + xh_D)} + \frac{b}{x} \log_e \left(\frac{1 + xh}{1 + xh_D} \right) \right. \\ &\quad \left. + \frac{c}{y} \log_e \left(\frac{1 + yh}{1 + yh_D} \right) + \frac{d}{z} \log_e \left(\frac{1 + zh}{1 + zh_D} \right) \right] \quad (C14) \end{aligned}$$

where

$$C_{D3} = \frac{-g_0 p_0 T_0}{p_0 (T_D - L h_D) (1 + kh_m)} \quad (C15)$$

$$x = \frac{1}{r}$$

$$y = \frac{L}{(T_D - L h_D)}$$

$$z = \frac{-K}{(1 + kh_m)}$$

$$a = \frac{x^2(x^2 + yz - yx - zx)}{(z - x)^2(y - x)^2}$$

$$\frac{b}{x} = \frac{x(2yz - xy - xz)}{(z - x)^2(y - x)^2}$$

$$\frac{c}{y} = \frac{-y^2}{(y - x)^2(z - y)}$$

$$\frac{d}{z} = \frac{z^2}{(z - x)^2(z - y)}$$

Equations (C4), (C7), (C11), and (C14) were used to compute the pressure ratios at the transition levels only in the tentative standard atmosphere. By dividing these pressure ratios by the pressure ratios at the same transition levels obtained by use of the equations in appendix B based on a constant value for the acceleration of gravity, a conversion factor was obtained for each of the several transition altitudes. Since it was impractical to use these complex equations for directly computing the pressure

ratios at all the levels recorded in tables IV and V, the values at these numerous intermediate levels were arrived at as follows:

(1) For each altitude a value for the conversion factor was computed by algebraic summation from the equation

$$\log_e\left(\frac{p_g}{p}\right) = \frac{p_0 T_0}{p_0 M_0} \sum_0^h (g_0 - g) \frac{M}{T} \Delta h \quad (C16)$$

where p_g is the pressure based on the variable value of g , and p is the pressure based on a constant value for the acceleration of gravity. In equation (C16) the proper value of g , T , and of M was substituted for each region of the atmosphere, according to equation (C2), (C5), and (C9), respectively.

(2) The values of p_g/p so computed were plotted against altitude to define the shape of the curve relating pressure ratios to altitude.

(3) The accurate values for the pressure ratio computed by equations (C4), (C7), (C11), and (C14) and by equations (B4), (B8), (B12), and (B14) were also plotted and another curve was drawn through these points representing the accurately computed ratios and faired according to the curve drawn through the points obtained by use of equation (C16).

(4) The curve arrived at from step (3) was then used to obtain conversion factors for each of the altitudes recorded in tables IV and V.

APPENDIX D

MOLECULAR MEAN FREE PATHS

Ratio of the Mean Free Paths of Molecules

The conventional equation for the mean free path of the molecules λ of a gas (reference 18) is

$$\lambda = \frac{1}{\pi \sqrt{2} N \sigma^2} \quad (D1)$$

Therefore the ratio of the mean free path at any altitude to the value at sea level is

$$\frac{\lambda}{\lambda_0} = \frac{N_0}{N} \left(\frac{\sigma_0}{\sigma} \right)^2 \quad (D2)$$

But

$$N_m = \rho \quad (D3)$$

and

$$\rho_0 = \frac{pM}{RT} \quad (D4)$$

Therefore

$$\frac{N_0}{N} = \frac{p_0}{p} \frac{T}{T_0} \frac{\rho}{\rho_0} \quad (D5)$$

and

$$\frac{\lambda}{\lambda_0} = \frac{p_0}{p} \frac{T}{T_0} \frac{\rho}{\rho_0} \left(\frac{\sigma_0}{\sigma} \right)^2 \quad (D6)$$

For all constituents of the atmosphere except oxygen in the region of dissociation,

$$\sigma = \sigma_0$$

In the absence of available data on the diameter of atoms of oxygen relative to that of molecular oxygen, and in consideration of the fact that the small difference in these two diameters of oxygen has an even smaller effect upon the average diameter of all atmospheric constituents, and for reasons of simplicity it is herein assumed for oxygen also that $\sigma = \sigma_0$. For the purpose of computing these tables therefore equation (D6) is simplified to

$$\frac{\lambda}{\lambda_0} = \frac{P_0 \cdot T}{P \cdot T_0} \frac{g}{g_0} \quad (D7)$$

Furthermore, in those computations that are based on a constant value for the acceleration of gravity

$$g = g_0$$

whence equation (D7) is further simplified to

$$\frac{\lambda}{\lambda_0} = \frac{P_0}{P} \frac{T}{T_0} \quad (D8)$$

Mean Free Paths of Molecules at Sea Level

The values of the mean free path of the molecules at sea level given in table I are for nitrogen and oxygen molecules in a normal atmospheric mixture of nitrogen and oxygen. These mean free paths are designated λ_n and λ_o , respectively. A weighted average of the foregoing mean free paths, based upon the relative volumes of nitrogen and oxygen in air is also included and is designated λ_{air} .

The mean free path of the nitrogen molecules in the atmosphere at sea level was computed by the following formula (p. 99 of reference 18):

$$\lambda_n = \frac{1}{\pi \sqrt{2} N_n \sigma_n^2 + \pi N_o \sigma_o^2 \frac{\sqrt{\bar{c}_n^2 + \bar{c}_o^2}}{\bar{c}_n}}$$

where

- N_n number of nitrogen molecules per unit volume of air
- N_o number of oxygen molecules per unit volume of air
- σ_n diameter of nitrogen molecules
- σ_o diameter of oxygen molecules
- $\bar{\sigma}$ average diameter of nitrogen and oxygen molecules
- \bar{c}_n average speed of nitrogen molecules
- \bar{c}_o average speed of oxygen molecules

Similarly, the mean free path of the oxygen molecules at sea level was computed by

$$\lambda_o = \frac{1}{\pi \sqrt{2} N_o \sigma_o^2 + \pi N_n \bar{\sigma}^2 \frac{\bar{c}_n^2 + \bar{c}_o^2}{\bar{c}_o}} \quad (D9)$$

The values for the average speeds \bar{c}_n and \bar{c}_o were obtained from the formula $\bar{c} = \sqrt{\frac{3RT}{M}}$. The values for σ were taken from appendix III, column 4, of reference 18. Values of N_n and N_o , the number of molecules of nitrogen and oxygen, respectively, per unit volume were calculated from the Loschmidt number and the relative volume of the nitrogen and oxygen in air at sea level.

APPENDIX E

VALUES OF CERTAIN CONSTANTS

Tentative Standard Atmosphere at Sea Level

The standard sea-level values for various properties of the atmosphere have been listed in reference 1, and sea-level values for certain other properties are listed in reference 5. Most of these previously listed values are adopted for use in computing the tables herein, but a few changes have been made. The changes are as follows:

Speed of sound. - The values for the speed of sound have been altered slightly to avoid the discrepancy which existed between the values previously listed and the values computed by the conventional equation

$$a_0 = \sqrt{\frac{\gamma_0 p_0}{\rho_0}} \quad (E1)$$

The values for a_0 listed in table I are computed according to equation (E1) by using the appropriate values for γ_0 , p_0 , and ρ_0 that are also listed in table I.

Density. - The values for density in the British engineering system has been changed from 0.002378 to 0.0023779 slugs per cubic foot to avoid discrepancies resulting when computations are based either on the standardized value for specific weight, 1.2255 kilograms per cubic meter (reference 1), or on the derived value for density.

Molecular mean free paths and molecular weight. - In addition to the various quantities previously given in references 1 and 5, the present paper lists molecular mean free paths and the average molecular weight of normal sea-level air. Molecular mean free paths for the nitrogen molecules and oxygen molecules in the normal air mixture have been computed and a weighted average for air has been taken, as described in appendix D. The average molecular weight of normal sea-level air is taken as 28.966 in accordance with reference 19.

Pressure.-- The value for pressure in the British engineering system has been changed from 407.1 or 407.2 inches of water at 15° C as used in reference 5 and reference 20, respectively, to 407.15 inches of water at 15° C. This value of 407.15 is the computed value corresponding to 760 millimeters of mercury based on the auxiliary constants and conversion factors listed in the last section of this appendix E.

Table of Sea-Level Values

The values for the various properties of the atmosphere at sea level corresponding to the adopted values for probable minimum and probable maximum temperatures are computed from the values corresponding to standard sea-level temperatures. All three sets of values used in both metric and British engineering systems of units are tabulated in table I. In some instances a quantity is listed in more than one unit, in either the metric or British system.

Auxiliary Constants and Conversion Factors

In addition to the atmospheric properties at sea level given in table I certain other basic constants and conversion factors are used in computing tables II to V. They are

Auxiliary constants:

Density of mercury at 0° C, gm/cm ³	13.5951
Standard acceleration of gravity, g ₀ , cm/sec ²	980.665
Density of water at 15° C, gm/ml	0.9991286
Radius of the earth at 45° latitude and at sea level, m	6,367,623

Conversion factors:

$$1 \text{ lb} = 453.5924 \text{ gm}$$

$$1 \text{ meter} = 3.280833 \text{ ft}$$

$$^{\circ}\text{K} = ^{\circ}\text{C} + 273$$

$$^{\circ}\text{F abs} = ^{\circ}\text{F} + 459.4$$

$$1 \text{ ml} = 1.000027 \text{ cm}^3$$

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TABLE I.— PROPERTIES OF THE ATMOSPHERE AT SEA LEVEL

Quantity	Symbol	Metric engineering system			British engineering system			
		Unit	At probable minimum temperature	At standard temperature	At probable maximum temperature	Unit	At probable minimum temperature	At standard temperature
Temperature	t_0	$^{\circ}\text{C}$	-48.0	15.0	47.0	$^{\circ}\text{F}$	-54.5	59.0
Absolute temperature	T_0	$^{\circ}\text{K}$	225.0	288.0	320.0	$^{\circ}\text{F}$ abs.	405.0	518.4
Pressure	p_0	mm Hg at 0°C	760	760	760	in. Hg at 32°F	29.9212	29.9212
		kg/m ²	10332.3	10332.3	10332.3	in. water at 15°C	407.15	407.15
Specific weight	w_0	dynes/cm ²	1.01325×10^6	1.01325×10^6	1.01325×10^6	lb/ft ²	2116.23	2116.23
Density	$\rho_0 = \frac{w_0}{g_0}$	kg/m ³	1.5636	1.2255	1.1030	lb/ft ³	0.097928	0.076506
Coefficient of viscosity	μ_0	dynes/cm ² /sec	1.5383	1.2018	1.0816	slugs/ft ³	0.0030437	0.0023779
Kinematic viscosity	$v_0 = \frac{\mu_0}{\rho_0}$	kg-sec ² /m ⁴	0.15995	0.12466	0.11247	lb-sec/ft ²	3.0420×10^{-7}	4.0455×10^{-7}
Speed of sound	a_0	m/sec	1.4852×10^{-6}	1.8187×10^{-6}	1.9751×10^{-6}	ft ² /sec	1.5665×10^{-4}	1.8903×10^{-4}
		km/hr	14565×10^{-8}	17835×10^{-8}	19369×10^{-8}	ft/sec	986.61	1116.22
Mean free path of nitrogen molecules	λ_n	m	5.76×10^{-8}	7.38×10^{-8}	8.20×10^{-8}	mph	672.69	761.06
Mean free path of oxygen molecules	λ_o	m	5.75×10^{-8}	7.36×10^{-8}	8.18×10^{-8}	knots	584.16	660.90
Mean free path of air molecules	λ_{air}	m	5.76×10^{-8}	7.37×10^{-8}	8.19×10^{-8}	ft	0.1891×10^{-6}	0.2421×10^{-6}
Average molecular weight	M_0	----	28.966	28.966	28.966	ft	0.1887×10^{-6}	0.2415×10^{-6}
Ratio of specific heats	γ_0	----	1.4	1.4	1.4	----	1.4	1.4
Relative volume of oxygen	r_0	----	0.2095	0.2095	0.2095	----	0.2095	0.2095

TABLES II AND III

PROPERTIES OF THE UPPER ATMOSPHERE
FOR TENTATIVE STANDARD TEMPERATURES
BASED ON AN ARBITRARY CONSTANT VALUE
OF GRAVITATIONAL FORCE

The following set of two tables (tables II and III) constitutes a consistent extension of the standard tables for the lower atmosphere (NACA Rep. No. 218). Consequently, altitudes in this set of tables which correspond to specified ambient-air pressures may be referred to as "tentative pressure altitudes," and those which correspond to a specified ambient-air density may be referred to as "tentative density altitudes" (NACA Rep. No. 474).

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TABLE II... PROPERTIES OF THE UPPER ATMOSPHERE FOR TENTATIVE STANDARD TEMPERATURES BASED ON AN ARBITRARY
CONSTANT VALUE OF GRAVITATIONAL FORCE - METRIC ENGINEERING SYSTEM

Altitude, h (m)	Absolute tempera- ture, T (°K)	Pressure, P (kg/m ²)	Pressure ratio, P/P ₀	Density, ρ (kg/m ³)	Density ratio, σ = P/P ₀	Specific weight, γ = P/g (kg/m ³)	Coefficient of viscosity, μ (kg-sec) m ²	Kinematic viscosity, ν = μ/ρ (m ² /sec)	Speed of sound, c (m/sec)	Mean free path of molecules, λ (m)
(a) For both day and night										
20,000	218.0	563.0	5.14x10 ⁻⁵	8.99x10 ⁻⁶	7.10x10 ⁻⁵	8.82x10 ⁻⁵	1.44x10 ⁻⁶	0.01607x10 ⁻²	296.0	0.00102x10 ⁻³
20,500	218.0	562.5	5.13x10 ⁻⁵	8.98x10 ⁻⁶	7.09x10 ⁻⁵	8.81x10 ⁻⁵	1.44x10 ⁻⁶	0.01738	296.0	0.00111
21,000	218.0	562.0	5.12x10 ⁻⁵	8.97x10 ⁻⁶	7.08x10 ⁻⁵	8.80x10 ⁻⁵	1.44x10 ⁻⁶	0.01860	296.0	0.00120
21,500	218.0	561.5	5.11x10 ⁻⁵	8.96x10 ⁻⁶	7.07x10 ⁻⁵	8.79x10 ⁻⁵	1.44x10 ⁻⁶	0.02033	296.0	0.00130
22,000	218.0	561.0	5.10x10 ⁻⁵	8.95x10 ⁻⁶	7.06x10 ⁻⁵	8.78x10 ⁻⁵	1.44x10 ⁻⁶	0.02199	296.0	0.00140
22,500	218.0	560.5	5.09x10 ⁻⁵	8.94x10 ⁻⁶	7.05x10 ⁻⁵	8.77x10 ⁻⁵	1.44x10 ⁻⁶	0.02378	296.0	0.00151
23,000	218.0	560.0	5.08x10 ⁻⁵	8.93x10 ⁻⁶	7.04x10 ⁻⁵	8.76x10 ⁻⁵	1.44x10 ⁻⁶	0.02557	296.0	0.00161
23,500	218.0	559.5	5.07x10 ⁻⁵	8.92x10 ⁻⁶	7.03x10 ⁻⁵	8.75x10 ⁻⁵	1.44x10 ⁻⁶	0.02736	296.0	0.00171
24,000	218.0	559.0	5.06x10 ⁻⁵	8.91x10 ⁻⁶	7.02x10 ⁻⁵	8.74x10 ⁻⁵	1.44x10 ⁻⁶	0.03008	296.0	0.00182
24,500	218.0	558.5	5.05x10 ⁻⁵	8.90x10 ⁻⁶	7.01x10 ⁻⁵	8.73x10 ⁻⁵	1.44x10 ⁻⁶	0.03281	296.0	0.00192
25,000	218.0	558.0	5.04x10 ⁻⁵	8.89x10 ⁻⁶	7.00x10 ⁻⁵	8.72x10 ⁻⁵	1.44x10 ⁻⁶	0.03554	296.0	0.00207
25,500	218.0	557.5	5.03x10 ⁻⁵	8.88x10 ⁻⁶	6.99x10 ⁻⁵	8.71x10 ⁻⁵	1.44x10 ⁻⁶	0.03828	296.0	0.00224
26,000	218.0	557.0	5.02x10 ⁻⁵	8.87x10 ⁻⁶	6.98x10 ⁻⁵	8.70x10 ⁻⁵	1.44x10 ⁻⁶	0.04105	296.0	0.00242
26,500	218.0	556.5	5.01x10 ⁻⁵	8.86x10 ⁻⁶	6.97x10 ⁻⁵	8.69x10 ⁻⁵	1.44x10 ⁻⁶	0.04475	296.0	0.00261
27,000	218.0	556.0	5.00x10 ⁻⁵	8.85x10 ⁻⁶	6.96x10 ⁻⁵	8.68x10 ⁻⁵	1.44x10 ⁻⁶	0.04843	296.0	0.00280
27,500	218.0	555.5	4.99x10 ⁻⁵	8.84x10 ⁻⁶	6.95x10 ⁻⁵	8.67x10 ⁻⁵	1.44x10 ⁻⁶	0.05206	296.0	0.00307
28,000	218.0	555.0	4.98x10 ⁻⁵	8.83x10 ⁻⁶	6.94x10 ⁻⁵	8.66x10 ⁻⁵	1.44x10 ⁻⁶	0.05571	296.0	0.00332
28,500	218.0	554.5	4.97x10 ⁻⁵	8.82x10 ⁻⁶	6.93x10 ⁻⁵	8.65x10 ⁻⁵	1.44x10 ⁻⁶	0.05938	296.0	0.00358
29,000	218.0	554.0	4.96x10 ⁻⁵	8.81x10 ⁻⁶	6.92x10 ⁻⁵	8.64x10 ⁻⁵	1.44x10 ⁻⁶	0.06295	296.0	0.00387
29,500	218.0	553.5	4.95x10 ⁻⁵	8.80x10 ⁻⁶	6.91x10 ⁻⁵	8.63x10 ⁻⁵	1.44x10 ⁻⁶	0.06652	296.0	0.00419
30,000	218.0	553.0	4.94x10 ⁻⁵	8.79x10 ⁻⁶	6.90x10 ⁻⁵	8.62x10 ⁻⁵	1.44x10 ⁻⁶	0.07000	296.0	0.00454
30,500	218.0	552.5	4.93x10 ⁻⁵	8.78x10 ⁻⁶	6.89x10 ⁻⁵	8.61x10 ⁻⁵	1.44x10 ⁻⁶	0.07367	296.0	0.00490
31,000	218.0	552.0	4.92x10 ⁻⁵	8.77x10 ⁻⁶	6.88x10 ⁻⁵	8.60x10 ⁻⁵	1.44x10 ⁻⁶	0.07734	296.0	0.00521
31,500	218.0	551.5	4.91x10 ⁻⁵	8.76x10 ⁻⁶	6.87x10 ⁻⁵	8.59x10 ⁻⁵	1.44x10 ⁻⁶	0.08101	296.0	0.00557
32,000	218.0	551.0	4.90x10 ⁻⁵	8.75x10 ⁻⁶	6.86x10 ⁻⁵	8.58x10 ⁻⁵	1.44x10 ⁻⁶	0.08468	296.0	0.00591
32,500	218.0	550.5	4.89x10 ⁻⁵	8.74x10 ⁻⁶	6.85x10 ⁻⁵	8.57x10 ⁻⁵	1.44x10 ⁻⁶	0.08835	296.0	0.00627
33,000	218.0	550.0	4.88x10 ⁻⁵	8.73x10 ⁻⁶	6.84x10 ⁻⁵	8.56x10 ⁻⁵	1.44x10 ⁻⁶	0.09202	296.0	0.00661
33,500	218.0	549.5	4.87x10 ⁻⁵	8.72x10 ⁻⁶	6.83x10 ⁻⁵	8.55x10 ⁻⁵	1.44x10 ⁻⁶	0.09569	296.0	0.00695
34,000	218.0	549.0	4.86x10 ⁻⁵	8.71x10 ⁻⁶	6.82x10 ⁻⁵	8.54x10 ⁻⁵	1.44x10 ⁻⁶	0.09936	296.0	0.00731
34,500	218.0	548.5	4.85x10 ⁻⁵	8.70x10 ⁻⁶	6.81x10 ⁻⁵	8.53x10 ⁻⁵	1.44x10 ⁻⁶	0.01032	296.0	0.00767
35,000	218.0	548.0	4.84x10 ⁻⁵	8.69x10 ⁻⁶	6.80x10 ⁻⁵	8.52x10 ⁻⁵	1.44x10 ⁻⁶	0.01390	296.0	0.00802
35,500	218.0	547.5	4.83x10 ⁻⁵	8.68x10 ⁻⁶	6.79x10 ⁻⁵	8.51x10 ⁻⁵	1.44x10 ⁻⁶	0.01747	296.0	0.00837
36,000	218.0	547.0	4.82x10 ⁻⁵	8.67x10 ⁻⁶	6.78x10 ⁻⁵	8.50x10 ⁻⁵	1.44x10 ⁻⁶	0.02104	296.0	0.00871
36,500	218.0	546.5	4.81x10 ⁻⁵	8.66x10 ⁻⁶	6.77x10 ⁻⁵	8.49x10 ⁻⁵	1.44x10 ⁻⁶	0.02461	296.0	0.00905
37,000	218.0	546.0	4.80x10 ⁻⁵	8.65x10 ⁻⁶	6.76x10 ⁻⁵	8.48x10 ⁻⁵	1.44x10 ⁻⁶	0.02818	296.0	0.00939
37,500	218.0	545.5	4.79x10 ⁻⁵	8.64x10 ⁻⁶	6.75x10 ⁻⁵	8.47x10 ⁻⁵	1.44x10 ⁻⁶	0.03175	296.0	0.00973
38,000	218.0	545.0	4.78x10 ⁻⁵	8.63x10 ⁻⁶	6.74x10 ⁻⁵	8.46x10 ⁻⁵	1.44x10 ⁻⁶	0.03532	296.0	0.01007
38,500	218.0	544.5	4.77x10 ⁻⁵	8.62x10 ⁻⁶	6.73x10 ⁻⁵	8.45x10 ⁻⁵	1.44x10 ⁻⁶	0.03889	296.0	0.01041
39,000	218.0	544.0	4.76x10 ⁻⁵	8.61x10 ⁻⁶	6.72x10 ⁻⁵	8.44x10 ⁻⁵	1.44x10 ⁻⁶	0.04246	296.0	0.01075
39,500	218.0	543.5	4.75x10 ⁻⁵	8.60x10 ⁻⁶	6.71x10 ⁻⁵	8.43x10 ⁻⁵	1.44x10 ⁻⁶	0.04603	296.0	0.01109
40,000	218.0	543.0	4.74x10 ⁻⁵	8.59x10 ⁻⁶	6.70x10 ⁻⁵	8.42x10 ⁻⁵	1.44x10 ⁻⁶	0.04960	296.0	0.01143
40,500	218.0	542.5	4.73x10 ⁻⁵	8.58x10 ⁻⁶	6.69x10 ⁻⁵	8.41x10 ⁻⁵	1.44x10 ⁻⁶	0.05317	296.0	0.01177
41,000	218.0	542.0	4.72x10 ⁻⁵	8.57x10 ⁻⁶	6.68x10 ⁻⁵	8.40x10 ⁻⁵	1.44x10 ⁻⁶	0.05674	296.0	0.01211
41,500	218.0	541.5	4.71x10 ⁻⁵	8.56x10 ⁻⁶	6.67x10 ⁻⁵	8.39x10 ⁻⁵	1.44x10 ⁻⁶	0.06031	296.0	0.01245
42,000	218.0	541.0	4.70x10 ⁻⁵	8.55x10 ⁻⁶	6.66x10 ⁻⁵	8.38x10 ⁻⁵	1.44x10 ⁻⁶	0.06388	296.0	0.01279
42,500	218.0	540.5	4.69x10 ⁻⁵	8.54x10 ⁻⁶	6.65x10 ⁻⁵	8.37x10 ⁻⁵	1.44x10 ⁻⁶	0.06745	296.0	0.01313
43,000	218.0	540.0	4.68x10 ⁻⁵	8.53x10 ⁻⁶	6.64x10 ⁻⁵	8.36x10 ⁻⁵	1.44x10 ⁻⁶	0.07102	296.0	0.01347
43,500	218.0	539.5	4.67x10 ⁻⁵	8.52x10 ⁻⁶	6.63x10 ⁻⁵	8.35x10 ⁻⁵	1.44x10 ⁻⁶	0.07459	296.0	0.01381
44,000	218.0	539.0	4.66x10 ⁻⁵	8.51x10 ⁻⁶	6.62x10 ⁻⁵	8.34x10 ⁻⁵	1.44x10 ⁻⁶	0.07816	296.0	0.01415
44,500	218.0	538.5	4.65x10 ⁻⁵	8.50x10 ⁻⁶	6.61x10 ⁻⁵	8.33x10 ⁻⁵	1.44x10 ⁻⁶	0.08173	296.0	0.01449
45,000	218.0	538.0	4.64x10 ⁻⁵	8.49x10 ⁻⁶	6.60x10 ⁻⁵	8.32x10 ⁻⁵	1.44x10 ⁻⁶	0.08530	296.0	0.01483
45,500	218.0	537.5	4.63x10 ⁻⁵	8.48x10 ⁻⁶	6.59x10 ⁻⁵	8.31x10 ⁻⁵	1.44x10 ⁻⁶	0.08887	296.0	0.01517
46,000	218.0	537.0	4.62x10 ⁻⁵	8.47x10 ⁻⁶	6.58x10 ⁻⁵	8.30x10 ⁻⁵	1.44x10 ⁻⁶	0.09244	296.0	0.01551
46,500	218.0	536.5	4.61x10 ⁻⁵	8.46x10 ⁻⁶	6.57x10 ⁻⁵	8.29x10 ⁻⁵	1.44x10 ⁻⁶	0.09598	296.0	0.01585
47,000	218.0	536.0	4.60x10 ⁻⁵	8.45x10 ⁻⁶	6.56x10 ⁻⁵	8.28x10 ⁻⁵	1.44x10 ⁻⁶	0.09955	296.0	0.01619
47,500	218.0	535.5	4.59x10 ⁻⁵	8.44x10 ⁻⁶	6.55x10 ⁻⁵	8.27x10 ⁻⁵	1.44x10 ⁻⁶	0.01032	296.0	0.01653
48,000	218.0	535.0	4.58x10 ⁻⁵	8.43x10 ⁻⁶	6.54x10 ⁻⁵	8.26x10 ⁻⁵	1.44x10 ⁻⁶	0.01389	296.0	0.01687
48,500	218.0	534.5	4.57x10 ⁻⁵	8.42x10 ⁻⁶	6.53x10 ⁻⁵	8.25x10 ⁻⁵	1.44x10 ⁻⁶	0.01746	296.0	0.01721
49,000	218.0	534.0	4.56x10 ⁻⁵	8.41x10 ⁻⁶	6.52x10 ⁻⁵	8.24x10 ⁻⁵	1.44x10 ⁻⁶	0.02103	296.0	0.01755
49,500	218.0	533.5	4.55x10 ⁻⁵	8.40x10 ⁻⁶	6.51x10 ⁻⁵	8.23x10 ⁻⁵	1.44x10 ⁻⁶	0.02460	296.0	0.01789
50,000	218.0	533.0	4.54x10 ⁻⁵	8.39x10 ⁻⁶	6.50x10 ⁻⁵	8.22x10 ⁻⁵	1.44x10 ⁻⁶	0.02817	296.0	0.01823
50,500	218.0	532.5	4.53x10 ⁻⁵	8.38x10 ⁻⁶	6.49x10 ⁻⁵	8.21x10 ⁻⁵	1.44x10 ⁻⁶	0.03174	296.0	0.01857
51,000	218.0	532.0	4.52x10 ⁻⁵	8.37x10 ⁻⁶	6.48x10 ⁻⁵	8.20x10 ⁻⁵	1.44x10 ⁻⁶	0.03531	296.0	0.01891
51,500	218.0	531.5	4.51x10 ⁻⁵	8.36x10 ⁻⁶	6.47x10 ⁻⁵	8.19x10 ⁻⁵	1.44x10 ⁻⁶	0.03888	296.0	0.01925
52,000	218.0	531.0	4.50x10 ⁻⁵	8.35x10 ⁻⁶	6.46x10 ⁻⁵	8.18x10 ⁻⁵	1.44x10 ⁻⁶	0.04245	296.0	0.01960
52,500	218.0	530.5	4.49x10 ⁻⁵	8.34x10 ⁻⁶	6.45x10 ⁻⁵	8.17x10 ⁻⁵	1.44x10 ⁻⁶	0.04602	296.0	0.01994
53,000	218.0	530.0	4.48x10 ⁻⁵	8.33x10 ⁻⁶	6.44x10 ⁻⁵	8.16x10 ⁻⁵	1.44x10 ⁻⁶	0.04959	296.0	0.02028
53,500	218.0	529.5	4.47x10 ⁻⁵	8.32x10 ⁻⁶	6.43x10 ⁻⁵	8.15x10 ⁻⁵	1.44x10 ⁻⁶	0.05316	296.0	0.02062
54,000										

TABLE II.—PROPERTIES OF THE UPPER ATMOSPHERE FOR TENTATIVE STANDARD TEMPERATURES BASED ON AN ARBITRARY
CONSTANT VALUE OF GRAVITATIONAL FORCE — METRIC ENGINEERING SYSTEM — Concluded

Altitude, h (m)	Absolute tempera- ture, T (°K)	Pressure, P (kg/m ²)	Pressure ratio, P/P ₀	Density, ρ (kg-sec ²) m ⁴	Density ratio, σ = ρ/ρ ₀	Specific weight, γ = ρg (kg/m ³)	Coefficient of viscosity, μ (kg-sec) m ²	Kinematic viscosity, ν = μ/ ρ (m ² /sec)	Speed of sound, a (m/sec)	Mean free path of molecules, λ (m)	
(b) For day only											
80,000	240.0	0.3256	3151×10 ⁻⁸	4726×10 ⁻⁹	3782×10 ⁻⁸	1635×10 ⁻⁸	1.568×10 ⁻⁶	0.3318	310.6	1.95×10 ⁻³	
81,000	240.0	0.3282	2733	4099	3280	1.568	0.3053	310.5	2.25		
82,000	240.0	0.2457	2371	3555	3485	1.568	0.4489	314.5	2.58		
83,000	240.0	0.2124	2056	3034	2467	1.568	0.3211	316.9	2.97		
84,000	243.6	0.1845	1785	2637	2110	1.568	0.2000	320.8	3.45		
85,000	247.3	0.1605	1553	2201	1809	1.567	0.1448	325.2	4.80		
86,000	250.9	0.1399	1344	1943	1554	1.567	0.0882	329.6	4.62		
87,000	254.6	0.1222	1183	1673	1338	1.567	1.021	333.9	5.32		
88,000	258.2	0.1070	1036	1443	1155	1.566	1.197	338.3	6.11		
89,000	261.9	0.09383	908.1	1248	998.6	1.565	1.385	342.7	6.99		
90,000	265.5	0.08810	852.7	1046	837.1	1.564	1.629	347.1	7.97		
91,000	269.2	0.07850	759.7	910.9	789.2	1.563	1.892	351.5	9.07		
92,000	272.8	0.07016	679.0	795.7	656.7	1.562	2.180	355.9	10.3		
93,000	276.5	0.06285	608.3	697.0	587.8	1.561	2.526	360.4	11.6		
94,000	280.1	0.05643	546.1	611.9	489.7	1.560	2.907	364.8	13.1		
95,000	283.8	0.05079	491.6	638.8	431.1	1.559	3.336	369.2	14.8		
96,000	287.4	0.04584	443.7	475.8	380.7	1.556	3.816	373.7	16.6		
97,000	291.1	0.04144	401.1	421.0	336.9	1.552	4.357	378.1	18.6		
98,000	294.7	0.03756	363.5	373.5	298.9	1.549	4.950	382.6	20.7		
99,000	298.4	0.03410	330.1	332.0	265.7	1.545	5.633	387.1	23.1		
100,000	302.0	0.03102	300.2	295.8	256.7	1.540	6.383	391.5	25.7		
101,000	305.7	0.02827	273.6	266.3	213.1	1.536	7.157	393.9	28.6		
102,000	309.3	0.02579	249.6	240.1	192.1	1.535	8.013	396.2	31.7		
103,000	313.0	0.02355	227.9	216.7	173.4	1.534	8.959	396.6	35.1		
104,000	316.6	0.02153	206.4	195.8	156.7	1.530	10.00	400.9	38.9		
105,000	320.3	0.01970	189.7	177.2	141.8	1.527	11.15	403.2	43.0		
106,000	323.9	0.01805	174.7	160.5	128.4	1.524	12.42	405.5	47.5		
107,000	327.6	0.01655	160.2	145.5	115.4	1.521	13.82	407.7	52.3		
108,000	331.2	0.01519	147.0	132.1	105.7	1.517	15.36	410.0	57.7		
109,000	334.9	0.01385	135.1	120.0	96.03	1.517	17.04	412.3	63.5		
110,000	338.5	0.01268	124.2	109.2	87.35	1.517	2.060	18.89	415.5	69.8	
111,000	342.2	0.01181	114.3	99.40	79.54	1.516	2.079	20.92	415.7	76.8	
112,000	345.8	0.01088	105.3	90.60	72.50	1.515	2.095	22.13	415.9	84.0	
113,000	349.5	0.01003	97.08	82.66	66.14	1.514	2.113	23.50	421.1	92.1	
114,000	353.1	0.009258	89.58	75.9	60.40	1.512	2.129	26.21	422.3	101	
115,000	356.7	0.008584	82.73	69.00	55.21	1.510	2.145	31.10	425.5	110	
116,000	360.4	0.007900	76.46	63.13	50.51	1.509	2.162	34.25	427.7	121	
117,000	364.1	0.007308	70.73	57.81	46.26	1.506	2.179	37.69	429.8	132	
118,000	367.7	0.006765	65.47	52.98	42.40	1.503	2.195	41.43	432.0	144	
119,000	371.4	0.006267	60.66	48.60	38.89	1.500	2.211	45.50	434.1	157	
120,000	375.0	0.005810	56.24	44.62	35.71	1.497	2.227	49.92	436.3	171	
(c) For night only											
80,000	240.0	0.3256	3151×10 ⁻⁸	4726×10 ⁻⁹	3782×10 ⁻⁸	1635×10 ⁻⁸	1.568×10 ⁻⁶	0.3318	310.6	1.95×10 ⁻³	
81,000	240.0	0.3282	2733	4099	3280	1.568	0.3025	310.6	2.25		
82,000	240.0	0.2450	2371	3555	3485	1.568	0.4411	314.6	2.59		
83,000	240.0	0.2124	2056	3034	2467	1.568	0.5085	316.6	2.99		
84,000	243.6	0.1845	1785	2637	2110	1.568	0.6021	312.9	3.49		
85,000	247.3	0.1605	1553	2201	1809	1.567	0.7110	315.3	4.07		
86,000	250.9	0.1399	1344	1943	1554	1.567	0.8376	317.6	4.74		
87,000	254.6	0.1222	1183	1673	1338	1.566	0.9834	319.9	5.51		
88,000	258.2	0.1070	1036	1443	1155	1.565	1.154	322.2	6.38		
89,000	261.9	0.09383	908.1	1248	998.6	1.565	1.350	324.4	7.38		
90,000	265.5	0.08823	797.8	1081	865.3	1.564	1.576	326.7	8.52		
91,000	269.2	0.07254	702.1	728.8	721.2	1.563	1.835	329.9	9.81		
92,000	272.8	0.06395	618.9	616.5	603.3	1.562	2.133	331.1	11.3		
93,000	276.5	0.05647	546.5	711.5	569.3	1.561	2.474	333.4	12.9		
94,000	280.1	0.04995	483.4	621.1	497.0	1.560	2.864	335.5	14.8		
95,000	283.8	0.04425	424.3	524.2	434.0	1.559	3.209	337.7	17.0		
96,000	287.4	0.03926	380.0	475.8	380.7	1.556	3.616	339.9	19.4		
97,000	291.1	0.03489	337.7	417.5	334.5	1.554	4.308	342.0	22.1		
98,000	294.7	0.03105	300.3	367.0	293.5	1.552	5.048	344.2	25.1		
99,000	298.4	0.02797	267.8	343.0	295.5	1.550	5.790	346.3	28.5		
100,000	302.0	0.02469	239.0	284.8	227.9	1.548	6.630	348.4	32.3		
101,000	305.7	0.02207	213.6	215.1	201.2	1.546	7.579	350.5	36.6		
102,000	309.3	0.01975	191.1	222.4	178.0	1.544	8.651	352.6	41.4		
103,000	313.0	0.01770	171.3	197.0	157.6	1.542	9.859	354.7	46.8		
104,000	316.6	0.01588	153.6	174.7	139.8	1.541	11.22	356.7	52.7		
105,000	320.3	0.01426	138.0	155.1	124.1	1.539	12.74	358.8	59.4		
106,000	323.9	0.01284	124.2	136.2	109.0	1.535	14.64	363.9	66.7		
107,000	327.6	0.01158	112.1	119.8	95.89	1.532	16.78	369.0	74.8		
108,000	331.2	0.01048	101.4	105.8	84.62	1.529	2.028	19.18	374.1	83.6	
109,000	334.9	0.009501	91.95	93.60	74.90	1.527	2.045	21.85	379.2	93.2	
110,000	338.5	0.008636	83.58	83.06	66.47	81.46	2.062	24.83	384.3	104	
111,000	342.2	0.007867	76.14	73.90	59.13	72.47	2.079	28.14	389.4	115	
112,000	345.8	0.007183	69.52	65.91	52.74	64.63	2.096	31.80	394.6	127	
113,000	349.5	0.006573	63.62	58.93	47.16	57.79	2.113	35.85	399.8	141	
114,000	353.1	0.006026	58.32	52.80	42.25	51.78	2.129	40.33	404.9	155	
115,000	356.8	0.005534	53.56	47.41	37.94	46.49	2.146	45.26	410.1	170	
116,000	360.4	0.005091	49.28	42.66	34.13	41.83	2.162	50.69	415.3	187	
117,000	364.1	0.004695	35.44	38.47	30.78	37.73	2.179	56.53	420.6	205	
118,000	367.7	0.004336	31.97	34.77	27.82	34.99	2.195	63.14	425.8	224	
119,000	371.4	0.004011	38.82	31.47	25.18	30.86	2.211	70.27	431.0	245	
120,000	375.0	0.003718	35.99	26.55	22.85	28.00	2.227	78.01	436.3	267	

¹The values for viscosity listed in these columns are not applicable at the higher altitudes where the mean free paths of the molecules are comparable to or longer than the dimensions of the body being considered. Furthermore, the values listed are based on the conventional Sutherland formula for normal air and, consequently, no allowance has been made for the effect of dissociated oxygen in the atmosphere at the higher levels.

TABLE III.—PROPERTIES OF THE UPPER ATMOSPHERE FOR TENTATIVE STANDARD TEMPERATURES BASED ON AN ARBITRARY
CONSTANT VALUE OF GRAVITATIONAL FORCE—BRITISH ENGINEERING SYSTEM

Altitude, (ft.)	Absolute temperature, (°F abs.)	Pressure, (lb./ft. ²)	Pressure ratio, P/P_0	Density, (slugs/ft. ³)	Density ratio, ρ/ρ_0	Specific weight, $\gamma = \rho g$ (lb./ft. ³)	Coefficient of viscosity, $\eta = \frac{\mu}{P}$ (lb.-sec./ft. ²)	Kinematic viscosity, $\nu = \frac{\eta}{\rho}$ (ft. ² /sec)	Speed of sound, (ft./sec.)	Mean free path of molecules, λ (ft.)
(a) For both day and night										
50,000	392.4	118.5	5512x10 ⁻⁵	1763x10 ⁻⁷	7418x10 ⁻⁵	5672x10 ⁻⁶	2.965x10 ⁻⁷	0.001680	971.1	0.00326x10 ⁻³
55,000	392.4	113.2	5350	1681	7068	5407	2.951	0.001761	971.1	0.00332
58,000	392.4	107.7	5192	1522	6525	5155	2.936	0.001848	971.1	0.00338
60,000	392.4	104.0	5050	1456	6123	4884	2.921	0.001939	971.1	0.00347
62,000	392.4	98.09	4835	1393	5634	4634	2.906	0.002034	971.1	0.00359
64,000	392.4	93.59	4635	1349	5135	4386	2.891	0.002133	971.1	0.00371
66,000	392.4	89.39	4442	1304	4636	4136	2.876	0.002232	971.1	0.00385
68,000	392.4	85.50	4261	1262	4137	3886	2.861	0.002330	971.1	0.00398
70,000	392.4	83.59	4090	1203	3636	3671	2.846	0.002429	971.1	0.00412
72,000	392.4	81.03	3930	1147	3135	3500	2.831	0.002520	971.1	0.00426
74,000	392.4	77.76	3801	1102	2634	3359	2.816	0.002610	971.1	0.00440
76,000	392.4	75.57	3686	1053	2133	3153	2.801	0.002704	971.1	0.00453
77,000	392.4	73.98	3576	1003	1632	2953	2.786	0.002797	971.1	0.00466
78,000	392.4	72.09	3475	957	1103	2754	2.771	0.002887	971.1	0.00477
79,000	392.4	69.81	3375	903.1	593.1	2556	2.756	0.002979	971.1	0.00487
80,000	392.4	68.01	3274	861.0	5421	2378	2.741	0.003071	971.1	0.00498
81,000	392.4	66.50	3175	820.9	4952	2201	2.726	0.003161	971.1	0.00511
82,000	392.4	65.20	3075	782.5	4525	2024	2.711	0.003250	971.1	0.00524
83,000	392.4	64.10	2975	746.2	4101	1847	2.696	0.003340	971.1	0.00537
84,000	392.4	63.10	2875	710.2	3775	1670	2.681	0.003429	971.1	0.00550
85,000	392.4	62.20	2775	674.5	3450	1493	2.666	0.003518	971.1	0.00563
86,000	392.4	61.40	2675	639.8	3125	1316	2.651	0.003607	971.1	0.00576
87,000	392.4	60.74	2575	605.5	2800	1139	2.636	0.003696	971.1	0.00589
88,000	392.4	59.50	2475	571.8	2475	952	2.621	0.003785	971.1	0.00602
89,000	392.4	58.39	2375	538.5	2150	765	2.606	0.003874	971.1	0.00615
90,000	392.4	57.39	2275	505.2	1831	578	2.591	0.003963	971.1	0.00628
91,000	392.4	56.40	2175	472.9	1512	391	2.576	0.004052	971.1	0.00641
92,000	392.4	55.50	2075	441.6	1203	203	2.561	0.004141	971.1	0.00654
93,000	392.4	54.60	1975	410.3	904	114	2.546	0.004230	971.1	0.00667
94,000	392.4	53.74	1875	379.1	605	108	2.531	0.004319	971.1	0.00680
95,000	392.4	52.94	1775	348.9	306	97	2.516	0.004408	971.1	0.00693
96,000	392.4	52.14	1675	318.7	205	86	2.501	0.004497	971.1	0.00706
97,000	392.4	51.34	1575	288.5	104	75	2.486	0.004586	971.1	0.00719
98,000	392.4	50.54	1475	258.3	53	64	2.471	0.004675	971.1	0.00732
99,000	392.4	49.74	1375	228.1	10	53	2.456	0.004764	971.1	0.00745
100,000	392.4	49.00	1275	197.9	10	42	2.441	0.004853	971.1	0.00758
102,000	392.4	47.31	1075	105.4	10	31	2.326	0.004942	971.1	0.00771
104,000	392.4	45.60	975	85.1	10	20	2.211	0.005031	971.1	0.00784
106,000	392.4	43.90	875	64.8	10	10	2.096	0.005120	971.1	0.00797
108,000	392.4	42.20	775	44.5	10	1	1.981	0.005209	971.1	0.01000
110,000	392.4	40.50	675	24.2	10	0	1.866	0.005298	971.1	0.01203
112,000	392.4	38.80	575	14.0	10	0	1.751	0.005387	971.1	0.01406
114,000	392.4	37.10	475	4.8	10	0	1.636	0.005476	971.1	0.01609
116,000	392.4	35.40	375	0.6	10	0	1.521	0.005565	971.1	0.01812
118,000	392.4	33.70	275	0	10	0	1.406	0.005654	971.1	0.01915
120,000	392.4	32.00	175	0	10	0	1.291	0.005743	971.1	0.02118
122,000	392.4	29.30	75	0	10	0	1.176	0.005832	971.1	0.02321
124,000	392.4	26.60	0	10	0	0	1.061	0.005921	971.1	0.02524
126,000	392.4	23.90	0	10	0	0	0.946	0.006010	971.1	0.02727
128,000	392.4	21.20	0	10	0	0	0.831	0.006100	971.1	0.02930
130,000	392.4	18.50	0	10	0	0	0.716	0.006189	971.1	0.03133
132,000	392.4	15.80	0	10	0	0	0.591	0.006278	971.1	0.03336
134,000	392.4	13.10	0	10	0	0	0.466	0.006367	971.1	0.03539
136,000	392.4	10.40	0	10	0	0	0.341	0.006456	971.1	0.03742
138,000	392.4	7.70	0	10	0	0	0.216	0.006545	971.1	0.03945
140,000	392.4	5.00	0	10	0	0	0.091	0.006634	971.1	0.04148
142,000	392.4	2.31	0	10	0	0	0.006	0.006723	971.1	0.04351
144,000	392.4	0.90	0	10	0	0	0.000	0.006812	971.1	0.04554
146,000	392.4	0.31	0	10	0	0	0.000	0.006901	971.1	0.04757
148,000	392.4	0.09	0	10	0	0	0.000	0.006990	971.1	0.04960
150,000	392.4	0.03	0	10	0	0	0.000	0.007079	971.1	0.05163
152,000	392.4	0.01	0	10	0	0	0.000	0.007168	971.1	0.05366
154,000	392.4	0.003	0	10	0	0	0.000	0.007257	971.1	0.05569
156,000	392.4	0.000	0	10	0	0	0.000	0.007346	971.1	0.05772
158,000	392.4	0.000	0	10	0	0	0.000	0.007435	971.1	0.05975
160,000	392.4	0.000	0	10	0	0	0.000	0.007524	971.1	0.06178
162,000	392.4	0.000	0	10	0	0	0.000	0.007613	971.1	0.06381
164,000	392.4	0.000	0	10	0	0	0.000	0.007702	971.1	0.06584
166,000	392.4	0.000	0	10	0	0	0.000	0.007791	971.1	0.06787
168,000	392.4	0.000	0	10	0	0	0.000	0.007880	971.1	0.06990
170,000	392.4	0.000	0	10	0	0	0.000	0.007969	971.1	0.07193
172,000	392.4	0.000	0	10	0	0	0.000	0.008058	971.1	0.07396
174,000	392.4	0.000	0	10	0	0	0.000	0.008147	971.1	0.07599
176,000	392.4	0.000	0	10	0	0	0.000	0.008236	971.1	0.07792
178,000	392.4	0.000	0	10	0	0	0.000	0.008325	971.1	0.07985
180,000	392.4	0.000	0	10	0	0	0.000	0.008414	971.1	0.08178
182,000	392.4	0.000	0	10	0	0	0.000	0.008503	971.1	0.08371
184,000	392.4	0.000	0	10	0	0	0.000	0.008592	971.1	0.08564
186,000	392.4	0.000	0	10	0	0	0.000	0.008681	971.1	0.08757
188,000	392.4	0.000	0	10	0	0	0.000	0.008770	971.1	0.08950
190,000	392.4	0.000	0	10	0	0	0.000	0.008859	971.1	0.09143
192,000	392.4	0.000	0	10	0	0	0.000	0.008948	971.1	0.09336
194,000	392.4	0.000	0	10	0	0	0.000	0.009037	971.1	0.09529
196,000	392.4	0.000	0	10	0	0	0.000	0.009126	971.1	0.09722
198,000	392.4	0.000	0	10	0	0	0.000	0.009215	971.1	0.09915
200,000	392.4	0.000	0	10	0	0	0.000	0.009304	971.1	0.01010
202,000	392.4	0.000	0	10	0	0	0.000	0.009393	971.1	0.01029
204,000	392.4	0.000	0	10	0	0	0.000	0.009482	971.1	0.01048
206,000	392.4	0.000	0	10	0	0	0.000	0.009571	971.1	0.01067
208,000	392.4	0.000	0	10	0	0	0.000	0.009660	971.1	0.01086
210,000	392.4	0.000	0	10	0	0	0.000	0.009749	971.1	0.01105
212,000	392.4	0.000	0	10	0	0	0.000	0.009838	971.1	0.01124
214,000	392.4	0.000	0	10	0	0	0.000	0.009927	971.1	0.01143
216,000	392.4	0.000	0	10	0	0	0.000	0.010016	971.1	0.01162
218,000	392.4	0.000	0	10	0	0	0.000	0.010105	971.1	0.01181
220,000	392.4	0.000	0	10	0	0	0.000	0.010194	971.1	0.01199
222,000	392.4	0.000	0	10	0</					

TABLE III.—PROPERTIES OF THE UPPER ATMOSPHERE FOR TENTATIVE STANDARD TEMPERATURES BASED ON AN ARBITRARY
CONSTANT VALUE OF GRAVITATIONAL FORCE—BRITISH ENGINEERING SYSTEM—Continued

Altitude, ^b (ft)	Absolute tempera- ture, ^b (°F abs.)	Pressure, ^b (lb/ft ²)	Pressure ratio, p/p_0	Density, ^b (slugs/ft ³)	Density ratio, $\sigma = \frac{p}{p_0}$	Specific weight, $w = gp$ (lb/ft ³)	Coefficient of viscosity, μ (lb sec/ft ²) (1)	Kinematic viscosity, $\nu = \frac{\mu}{w}$ (ft ² /sec) (1)	Speed of sound, (ft/sec)	Mean free path of molecules, λ (ft)
(b) For day only										
262,467	432.0	0.06669	3.151×10^{-5}	89.9×10^{-9}	3.782×10^{-5}	2.893×10^{-6}	3.212×10^{-7}	3.572	1019	6.4×10^{-3}
264,000	432.0	0.06241	2.949	83.75	3.522	2.695	3.212	3.835	1022	6.84
266,000	432.0	0.05724	2.705	76.33	3.210	2.456	3.212	4.208	1026	7.45
268,000	432.0	0.05257	2.484	69.65	2.929	2.241	3.212	4.612	1030	8.12
270,000	432.0	0.04829	2.282	63.59	2.574	2.046	3.212	5.051	1034	8.83
272,006	432.0	0.04438	2.097	58.07	2.142	1.868	3.212	5.531	1038	9.61
272,309	432.0	0.04381	2.070	57.26	2.148	1.842	3.212	5.610	1038	9.74
274,000	435.4	0.04082	1.929	52.67	2.215	1.695	3.232	6.136	1046	10.5
276,000	439.4	0.03780	1.776	47.77	2.009	1.537	3.257	6.818	1054	11.5
278,000	443.4	0.03469	1.638	43.42	1.826	1.397	3.282	7.559	1063	12.6
280,000	447.4	0.03200	1.512	39.45	1.659	1.269	3.306	8.380	1072	13.8
282,000	451.4	0.02956	1.397	35.91	1.510	1.155	3.331	9.273	1081	14.1
284,000	455.4	0.02736	1.293	32.74	1.377	1.053	3.355	10.25	1089	14.4
286,000	459.4	0.02535	1.198	29.89	1.257	0.9616	3.379	11.30	1098	17.9
288,000	463.4	0.02351	1.111	27.32	1.149	0.8791	3.403	12.46	1107	19.5
290,000	467.4	0.02184	1.032	25.02	1.052	0.8048	3.427	13.70	1116	21.1
292,000	471.4	0.02029	0.9588	22.91	0.9635	0.7371	3.451	15.06	1124	22.9
294,000	475.4	0.01888	0.8920	21.01	0.8837	0.6761	3.475	16.54	1133	24.9
296,000	479.4	0.01759	0.8310	19.30	0.8117	0.6210	3.499	18.13	1142	26.9
298,000	483.4	0.01639	0.7746	17.74	0.7450	0.5707	3.523	19.86	1151	29.1
300,000	487.4	0.01530	0.7228	16.32	0.6865	0.5252	3.546	21.73	1160	31.5
302,000	491.4	0.01428	0.6750	15.03	0.6322	0.4837	3.569	23.75	1169	34.0
304,000	495.4	0.01336	0.6314	13.87	0.5833	0.4453	3.593	25.90	1177	36.6
306,000	499.4	0.01250	0.5908	12.80	0.5384	0.4119	3.616	28.25	1186	39.4
308,000	503.4	0.01170	0.5521	11.82	0.4972	0.3804	3.639	30.79	1195	42.5
310,000	507.4	0.01098	0.5185	10.94	0.4599	0.3519	3.662	33.47	1204	45.7
312,000	511.5	0.01030	0.4886	10.13	0.4259	0.3258	3.685	36.28	1213	49.0
314,000	515.5	0.009671	0.4570	9.365	0.3947	0.3020	3.708	39.31	1222	52.6
316,000	519.5	0.009091	0.4296	8.705	0.3661	0.2801	3.731	42.06	1231	56.4
318,000	523.5	0.008550	0.4040	8.082	0.2600	0.2599	3.754	46.45	1240	60.5
320,000	527.5	0.008050	0.3804	7.509	0.3158	0.2416	3.777	50.30	1248	64.7
322,000	531.5	0.007585	0.3584	6.984	0.2937	0.2247	3.799	54.40	1257	69.2
324,000	535.5	0.007153	0.3380	6.504	0.2735	0.2092	3.822	58.75	1266	73.9
326,000	539.5	0.006744	0.3187	6.054	0.2536	0.1948	3.844	63.50	1275	79.0
328,000	543.6	0.006368	0.3009	5.645	0.2374	0.1816	3.867	68.48	1284	84.3
330,000	547.5	0.006012	0.2881	5.268	0.2234	0.1701	3.887	68.71	1285	84.5
332,000	551.5	0.005686	0.2687	4.965	0.2088	0.1597	3.911	73.54	1289	89.9
334,000	555.5	0.005377	0.2511	4.661	0.1950	0.1500	3.933	78.77	1294	95.8
336,000	559.5	0.005087	0.2404	4.380	0.1812	0.1409	3.955	84.38	1298	102
338,000	563.5	0.004812	0.2274	4.114	0.1730	0.1324	3.977	90.30	1303	109
340,000	567.5	0.004556	0.2153	3.866	0.1626	0.1244	3.999	103.4	1312	123
342,000	571.5	0.004315	0.2039	3.635	0.1529	0.1170	4.021	110.5	1317	131
344,000	575.5	0.004091	0.1933	3.424	0.1440	0.1102	4.043	118.1	1322	139
346,000	579.5	0.003875	0.1831	3.220	0.1354	0.1036	4.065	126.2	1326	148
348,000	583.5	0.003674	0.1736	3.032	0.1275	0.09755	4.086	134.8	1331	157
350,000	587.5	0.003485	0.1647	2.858	0.1202	0.09196	4.108	143.7	1335	167
352,000	591.5	0.0033306	0.1562	2.692	0.1132	0.08660	4.129	153.4	1340	177
354,000	595.5	0.003136	0.1482	2.537	0.1067	0.08163	4.151	163.6	1344	188
356,000	599.5	0.002978	0.1407	2.392	0.1006	0.07697	4.172	174.4	1349	199
358,000	603.5	0.002829	0.1337	2.258	0.09495	0.07264	4.193	185.7	1353	211
360,000	607.5	0.002690	0.1271	2.132	0.08967	0.06860	4.214	197.7	1358	223
362,000	611.5	0.002556	0.1208	2.013	0.08466	0.06477	4.236	210.4	1362	236
364,000	615.5	0.002429	0.1148	1.901	0.07994	0.06116	4.257	223.9	1367	250
366,000	619.5	0.002311	0.1092	1.796	0.07554	0.05779	4.278	238.2	1371	265
368,000	623.6	0.002199	0.1039	1.688	0.07142	0.05464	4.299	253.2	1376	280
370,000	627.6	0.002092	0.0987	1.606	0.06763	0.05166	4.319	268.9	1380	296
372,000	631.6	0.001992	0.09411	1.519	0.06387	0.04886	4.340	285.7	1384	313
374,000	635.6	0.001897	0.08982	1.437	0.06044	0.04624	4.361	303.5	1389	331
376,000	639.6	0.001806	0.08536	1.360	0.05720	0.04376	4.382	322.6	1393	350
378,000	643.6	0.001721	0.08133	1.288	0.05416	0.04144	4.402	341.6	1398	370
380,000	647.6	0.001640	0.07751	1.220	0.05130	0.03925	4.423	362.5	1402	390
382,000	651.6	0.001564	0.07390	1.156	0.04861	0.03719	4.443	384.3	1406	411
384,000	655.6	0.001492	0.07049	1.096	0.04609	0.03526	4.464	407.3	1411	434
386,000	659.6	0.001423	0.06724	1.039	0.04369	0.03343	4.484	431.6	1415	458
388,000	663.6	0.001358	0.06417	0.986	0.04145	0.03171	4.504	457.0	1419	483
390,000	667.6	0.001296	0.06126	0.9352	0.03933	0.03009	4.525	483.9	1423	509
392,000	671.6	0.001237	0.05877	0.8872	0.03731	0.02854	4.545	512.3	1426	536
393,700	675.0	0.001190	0.05624	0.8491	0.03571	0.02732	4.562	537.3	1431	560

¹The values for viscosity listed in these columns are not applicable at the higher altitudes where the mean free paths of the molecules are comparable to or longer than the dimensions of the body being considered. Furthermore, the values listed are based on the conventional Sutherland formula for normal air and, consequently, no allowance has been made for the effect of dissociated oxygen in the atmosphere at the higher levels.

TABLE III.—PROPERTIES OF THE UPPER ATMOSPHERE FOR TENTATIVE STANDARD TEMPERATURES BASED ON AN ARBITRARY
CONSTANT VALUE OF GRAVITATIONAL FORCE—BRITISH ENGINEERING SYSTEM—Concluded

Altitude, h (ft)	Absolute tempera- ture, T (°F abs.)	Pressure, P (lb/ft ²)	Pressure ratio, P/P ₀	Density, P (slugs/ft ³)	Density ratio, σ = P/P ₀	Specific Weight, w = gp (lb/ft ³)	Coefficient of viscosity, μ = μ ₀ P ² (lb-sec/ft ²) (1)	Kinematic viscosity, ν = μ/P (ft ² /sec) (1)	Speed of sound, a (ft/sec)	Mean free path of molecules, λ (ft)
(c) For night only										
262,467	432.0	0.06669	3.151x10 ⁻⁵	89.93x10 ⁻⁹	3.782x10 ⁻⁵	2.893x10 ⁻⁶	3.212x10 ⁻⁷	3.572	1019	6.40x10 ⁻³
264,000	432.0	0.06239	2.948	84.13	3.538	2.707	3.212	3.818	1019	6.84
266,000	432.0	0.05720	2.703	77.14	3.244	2.482	3.212	4.164	1019	7.46
268,000	432.0	0.05246	2.479	70.74	2.975	2.276	3.212	4.541	1019	8.13
270,000	432.0	0.04810	2.273	64.87	2.728	2.087	3.212	4.951	1016	8.87
272,000	432.0	0.04410	2.084	59.47	2.501	1.913	3.212	5.401	1019	9.67
272,309	432.0	0.04351	2.056	58.67	2.467	1.887	3.212	5.575	1029	9.80
274,000	435.4	0.04044	1.911	54.10	2.275	1.741	3.232	5.974	1023	10.6
276,000	439.4	0.03712	1.754	49.20	2.069	1.583	3.237	6.620	1028	11.7
278,000	443.4	0.03408	1.611	44.80	1.884	1.441	3.282	7.326	1032	12.8
280,000	447.4	0.03134	1.481	40.80	1.716	1.313	3.306	8.103	1037	14.1
282,000	451.4	0.02884	1.363	37.24	1.566	1.198	3.331	8.945	1042	15.5
284,000	455.4	0.02656	1.252	33.98	1.429	1.093	3.355	9.873	1046	16.9
286,000	459.4	0.02446	1.150	31.01	1.304	0.9976	3.379	10.90	1051	18.5
288,000	463.4	0.02256	1.086	28.34	1.192	0.9120	3.403	12.01	1055	20.3
290,000	467.4	0.02081	0.9832	25.92	1.090	0.8339	3.427	13.22	1060	22.0
292,000	471.4	0.01921	0.9079	23.74	0.9984	0.7638	3.451	14.54	1064	24.2
294,000	475.4	0.01774	0.8384	21.74	0.9142	0.6994	3.475	15.98	1069	26.5
296,000	479.4	0.01640	0.7748	19.92	0.8378	0.6410	3.499	17.57	1073	28.9
298,000	483.4	0.01517	0.7168	18.28	0.7887	0.5881	3.523	19.27	1078	31.5
300,000	487.4	0.01406	0.6663	16.80	0.7065	0.5405	3.546	21.11	1082	34.2
302,000	491.4	0.01302	0.6151	15.43	0.5689	0.4964	3.569	23.13	1087	37.3
304,000	495.4	0.01206	0.5699	14.18	0.5063	0.4562	3.593	25.34	1091	40.6
306,000	499.4	0.01119	0.5286	13.05	0.5487	0.4198	3.616	27.71	1096	44.1
308,000	503.4	0.01038	0.4906	12.01	0.5952	0.3865	3.639	30.30	1100	47.9
310,000	507.4	0.009542	0.4556	11.07	0.6454	0.3551	3.662	33.08	1104	52.0
312,000	511.5	0.008953	0.4233	10.20	0.4290	0.3282	3.685	35.13	1109	56.4
314,000	515.5	0.008327	0.3935	9.409	0.3957	0.3027	3.708	39.41	1113	61.1
316,000	519.5	0.007745	0.3660	8.686	0.3653	0.2795	3.731	42.95	1117	66.2
318,000	523.5	0.007210	0.3407	8.023	0.3374	0.2581	3.754	46.79	1122	71.7
320,000	527.5	0.006711	0.3171	7.410	0.3116	0.2384	3.777	50.97	1126	77.6
322,000	531.5	0.006253	0.2955	6.853	0.2205	0.2205	3.799	55.44	1130	83.8
324,000	535.5	0.005826	0.2753	6.337	0.2665	0.2039	3.822	60.31	1134	90.8
326,000	539.5	0.005437	0.2569	5.871	0.2468	0.1883	3.844	65.47	1139	98.0
328,000	543.5	0.005073	0.2397	5.436	0.2285	0.1749	3.867	71.14	1143	106
330,000	547.5	0.004736	0.2238	5.039	0.2119	0.1621	3.889	77.18	1147	114
332,000	551.5	0.004423	0.2090	4.673	0.1965	0.1503	3.911	83.69	1151	123
334,000	555.5	0.004133	0.1853	4.335	0.1823	0.1395	3.933	90.73	1155	133
336,000	559.5	0.003854	0.1826	4.023	0.1692	0.1294	3.955	98.31	1160	143
338,000	563.5	0.003617	0.1709	3.738	0.1572	0.1203	3.977	106.4	1164	154
340,000	567.5	0.003384	0.1599	3.474	0.1451	0.1118	3.999	115.1	1168	166
342,000	571.5	0.003166	0.1496	3.227	0.1357	0.1038	4.021	124.6	1172	178
344,000	575.5	0.002967	0.1402	3.003	0.1263	0.09663	4.043	134.6	1176	192
344,487	576.5	0.002920	0.1380	2.951	0.1241	0.09494	4.048	137.2	1177	195
346,000	579.5	0.002781	0.1314	2.777	0.1168	0.08936	4.065	146.4	1185	206
348,000	583.5	0.002611	0.1234	2.568	0.1080	0.08263	4.086	159.1	1195	221
350,000	587.5	0.002453	0.1159	2.376	0.09992	0.07644	4.108	172.9	1205	237
352,000	591.5	0.002305	0.1089	2.199	0.09248	0.07075	4.129	187.3	1215	253
354,000	595.5	0.002169	0.1025	2.039	0.08575	0.06560	4.151	203.6	1226	271
356,000	599.5	0.002041	0.09546	1.891	0.07951	0.06083	4.172	220.6	1236	290
358,000	603.5	0.001924	0.09090	1.756	0.07383	0.05748	4.193	238.8	1246	310
360,000	607.5	0.001815	0.08576	1.632	0.06864	0.05251	4.214	258.2	1256	331
362,000	611.5	0.001714	0.08098	1.519	0.06388	0.04887	4.236	278.9	1267	353
364,000	615.5	0.001618	0.07648	1.414	0.05947	0.04550	4.257	301.1	1277	376
366,000	619.5	0.001531	0.07238	1.319	0.05546	0.04243	4.278	324.3	1287	400
368,000	623.6	0.001449	0.06848	1.231	0.05175	0.03959	4.299	349.2	1297	425
370,000	627.6	0.001373	0.06488	1.149	0.04834	0.03698	4.319	375.9	1308	451
372,000	631.6	0.001302	0.06151	1.075	0.04520	0.03458	4.340	403.7	1318	479
374,000	635.6	0.001235	0.05836	1.006	0.04229	0.03235	4.361	433.5	1328	508
376,000	639.6	0.001172	0.05537	0.9409	0.03957	0.03027	4.382	465.7	1339	539
378,000	643.6	0.001113	0.05260	0.8817	0.03708	0.02837	4.402	499.3	1349	571
380,000	647.6	0.001058	0.05000	0.8268	0.03477	0.02660	4.423	535.0	1359	604
382,000	651.6	0.001007	0.04757	0.7761	0.03264	0.02427	4.443	572.5	1370	639
384,000	655.6	0.0009582	0.04528	0.7288	0.03065	0.02345	4.464	612.5	1381	676
386,000	659.6	0.0009127	0.04313	0.6851	0.02881	0.02204	4.484	654.5	1391	714
388,000	663.6	0.0008702	0.04112	0.6444	0.02710	0.02073	4.504	698.9	1401	754
390,000	667.6	0.0008396	0.03920	0.6064	0.02550	0.01951	4.525	746.2	1412	795
392,000	671.6	0.0007917	0.03741	0.5712	0.02402	0.01838	4.545	795.7	1422	838
393,700	675.0	0.0007614	0.03598	0.5434	0.02285	0.01748	4.562	839.5	1431	875

¹The values for viscosity listed in these columns are not applicable at the higher altitudes where the mean free paths of the molecules are comparable to or longer than the dimensions of the body being considered. Furthermore, the values listed are based on the conventional Sutherland formula for normal air and, consequently, no allowance has been made for the effect of dissociated oxygen in the atmosphere at the higher levels.

TABLES IV AND V

PROPERTIES OF THE UPPER ATMOSPHERE
FOR TENTATIVE STANDARD TEMPERATURES
BASED ON AN INVERSE SQUARE VARIATION
OF GRAVITATIONAL FORCE

The following set of two tables (tables IV and V) does not constitute a consistent extension of the standard tables for the lower atmosphere (NACA Rep. No. 218) but takes into account the inverse square law of gravitational attraction and, consequently, the values in these tables are more accurate than those in tables II and III.

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TABLE IV -- PROPERTIES OF THE UPPER ATMOSPHERE FOR TENTATIVE STANDARD TEMPERATURES BASED ON AN
INVERSE SQUARE VARIATION OF GRAVITATIONAL FORCE - METRIC ENGINEERING SYSTEM

Altitude, h (m)	Absolute tempera- ture, T (°K)	Pressure, P (kg/m ²)	Pressure ratio, P/P ₀	Density, ρ (kg/m ³)	Density ratio, σ = ρ/ρ ₀	Specific weight, w = g/ρ (kg/m ³)	Coefficient of viscosity, μ (kg/sec) x 10 ⁻⁵	Kinematic viscosity, ν = μ/ ρ (m ² /sec)	Speed of sound, U = P/ ρ (m/sec)	Mean free path of molecules, λ (m)
(a) For both day and night										
20,000	218.0	568.4	5501 x 10 ⁻⁵	908 x 10 ⁻⁶	7365 x 10 ⁻⁵	8849 x 10 ⁻⁵	1.446 x 10 ⁻⁶	0.01592 x 10 ⁻²	296.0	0.00101 x 10 ⁻³
20,500	218.0	552.4	5389	8402	7245	8656	1.446	0.01563	296.0	0.00118
21,000	218.0	536.4	4935	7759	7003	7976	1.446	0.02011	296.0	0.00127
21,500	218.0	499.9	4355	5750	5122	6978	1.446	0.02713	296.0	0.00136
22,000	218.0	4629	4029	5651	4523	5993	1.446	0.02346	296.0	0.00149
22,500	218.0	395.1	3767	6151	4923	5553	1.446	0.02398	296.0	0.00161
23,000	218.0	356.3	3448	5693	4556	5128	1.446	0.02745	296.0	0.00173
23,500	218.0	329.6	3190	5266	4214	4745	1.446	0.02674	296.0	0.00185
24,000	218.0	303.0	2992	4873	3859	4747	1.446	0.02707	296.0	0.00197
24,500	218.0	244.2	4731	4308	3007	4308	1.446	0.03097	296.0	0.00203
25,000	218.0	261.0	5256	4171	3338	4059	1.446	0.03466	296.0	0.00219
25,500	218.0	241.5	5337	5068	3755	3474	1.446	0.03745	296.0	0.00237
26,000	218.0	223.4	5163	3570	2657	3213	1.446	0.04048	296.0	0.00256
26,500	218.0	206.7	5001	3303	2643	2572	1.446	0.03765	296.0	0.00276
27,000	218.0	191.3	1591	3026	2463	2450	1.446	0.04737	296.0	0.00295
27,500	218.0	174.8	1512	2668	2094	2514	1.446	0.05123	296.0	0.00313
28,000	218.0	156.8	1458	2617	1937	2353	1.446	0.05521	296.0	0.00330
28,500	218.0	140.2	1357	2240	1793	2177	1.446	0.06454	296.0	0.00347
29,000	218.0	129.7	1255	2073	1659	2014	1.446	0.06975	296.0	0.00440
29,500	218.0	120.1	1162	1818	1335	1861	1.446	0.07736	296.0	0.00476
30,000	218.0	111.1	1072	1735	1120	1724	1.446	0.08187	296.0	0.00514
30,500	218.0	102.8	994	1643	1014	1595	1.446	0.08805	296.0	0.00555
31,000	218.0	95.09	920.4	1413	916	1475	1.446	0.09515	296.0	0.00600
31,500	218.0	87.99	951.6	1406	1125	1365	1.446	0.10268	296.0	0.00649
32,000	218.0	81.47	788.5	1260	1025	1243	1.446	0.11126	296.0	0.00712
32,500	218.0	75.54	731.1	1188	934.4	1143	1.446	0.12174	296.0	0.00811
33,000	218.0	70.12	678.3	1067	844.4	1029	1.446	0.13269	296.0	0.00934
33,500	218.0	65.26	630.7	780.7	730.7	1156	1.446	0.14566	296.0	0.0102
34,000	218.0	60.63	598.8	693.6	725.1	807.0	1.446	0.1733	296.0	0.0226
34,500	240.0	56.48	586.6	819.7	659.9	755.1	1.568	0.19113	310.6	0.0111
35,000	240.0	52.67	509.8	752.9	602.4	703.2	1.568	0.2109	312.6	0.0121
35,500	247.3	49.17	475.7	692.4	554.1	615.5	1.568	0.23242	315.3	0.0132
36,000	240.0	45.27	44.7	597.9	528.2	628.0	1.568	0.25233	317.0	0.0143
36,500	240.0	40.24	390.4	540.5	434.1	502.0	1.568	0.27223	318.7	0.0154
37,000	240.0	37.71	365.0	501.3	405.1	486.0	1.568	0.29722	320.4	0.0165
37,500	240.0	35.37	342.3	465.7	371.1	449.5	1.568	0.31623	322.0	0.0182
38,000	240.0	33.31	321.3	424.9	343.6	416.5	1.568	0.33774	323.6	0.0196
38,500	240.0	31.11	302.0	396.2	318.6	395.3	1.568	0.40114	325.2	0.0212
39,000	240.0	29.48	284.0	369.5	295.6	358.0	1.568	0.43777	326.8	0.0226
39,500	240.0	27.52	267.4	313.1	275.4	329.1	1.568	0.47677	328.4	0.0246
40,000	240.0	26.02	251.8	313.1	227.7	267.6	1.568	0.51877	329.9	0.0265
41,000	247.3	24.53	237.4	297.0	227.7	267.6	1.568	0.51777	330.6	0.0285
42,000	240.0	23.14	224.0	275.7	221.4	267.9	1.568	0.52233	331.3	0.0305
43,000	240.0	21.75	209.8	247.0	204.7	249.0	1.568	0.52233	332.0	0.0325
44,000	240.0	20.36	195.6	220.6	192.6	224.9	1.568	0.52774	332.7	0.0347
45,000	240.0	19.06	180.7	198.9	179.9	207.0	1.568	0.54033	333.4	0.0364
46,000	240.0	18.06	174.7	187.7	168.2	203.4	1.568	0.59075	334.1	0.0432
47,000	240.0	17.06	160.3	194.7	157.4	190.3	1.568	0.9790	334.8	0.0462
48,000	240.0	16.06	150.3	184.1	147.3	178.1	1.568	1.053	335.5	0.0493
49,000	240.0	15.06	141.9	172.5	138.1	166.9	1.568	1.135	336.2	0.0526
50,000	240.0	14.06	141.9	161.8	129.5	166.9	1.568	1.223	336.9	0.0561
51,000	240.0	13.06	134.8	151.8	121.5	166.8	1.568	1.315	337.6	0.0596
52,000	240.0	12.06	134.2	129.9	114.1	137.8	1.568	1.412	338.3	0.0637
53,000	240.0	11.06	127.8	124.0	107.3	129.3	1.568	1.505	339.0	0.0677
54,000	240.0	10.06	118.8	111.7	108.6	124.6	1.568	1.600	339.7	0.0716
55,000	240.0	9.06	106.3	101.7	98.37	107.9	1.568	1.704	340.4	0.0755
56,000	240.0	8.06	101.2	95.2	94.21	101.6	1.568	1.804	341.1	0.0818
57,000	240.0	7.06	95.2	92.37	88.37	95.80	1.568	1.912	341.8	0.0871
58,000	240.0	6.06	87.51	90.12	82.11	87.00	1.568	2.024	342.5	0.0930
59,000	240.0	5.06	85.50	85.32	85.73	82.91	1.568	2.135	343.2	0.106
60,000	240.0	4.06	82.23	79.59	81.86	85.51	1.568	2.246	343.9	0.116
61,000	240.0	3.06	7.858	75.86	73.03	62.44	1.568	2.357	344.6	0.126
62,000	240.0	2.06	7.471	74.90	74.37	62.51	1.568	2.468	345.3	0.136
63,000	240.0	1.06	7.171	69.86	72.83	62.47	1.568	2.579	346.0	0.146
64,000	240.0	0.06	7.047	65.65	61.95	62.47	1.568	2.689	346.7	0.156
65,000	240.0	0.06	6.844	57.53	51.91	64.39	1.568	2.799	347.4	0.166
66,000	240.0	0.06	6.704	56.17	50.37	64.39	1.568	2.909	348.1	0.176
67,000	240.0	0.06	6.569	48.86	27.49	59.92	1.568	3.020	348.8	0.186
68,000	240.0	0.06	6.439	35.61	26.33	59.92	1.568	3.131	349.5	0.196
69,000	240.0	0.06	6.315	22.41	20.20	28.27	1.568	3.237	350.2	0.206
70,000	240.0	0.06	6.217	21.26	24.19	19.75	1.568	3.347	350.9	0.217
71,000	240.0	0.06	6.109	20.16	23.45	19.53	1.568	3.457	351.6	0.227
72,000	240.0	0.06	6.003	19.04	21.25	19.27	1.568	3.568	352.3	0.238
73,000	240.0	0.06	5.903	9.032	20.47	19.94	1.568	3.678	353.0	0.249
74,000	240.0	0.06	5.828	7.973	10.65	9.63	1.568	3.788	353.7	0.260
75,000	240.0	0.06	5.765	7.077	8.77	10.01	1.568	3.898	354.4	0.271
76,000	240.0	0.06	5.705	6.207	8.77	9.03	1.568	3.909	355.1	0.281
77,000	240.0	0.06	5.654	5.457	7.67	8.415	1.568	3.920	355.8	0.291
78,000	240.0	0.06	5.605	4.765	7.676	7.502	1.568	3.931	356.5	0.301
79,000	240.0	0.06	5.561	4.161	6.49	6.739	1.568	3.942	357.2	0.311
80,000	240.0	0.06	5.475	3.677	5.334	5.983	1.568	3.953	357.9	0.321

TABLE IV. — PROPERTIES OF THE UPPER ATMOSPHERE FOR TENTATIVE STANDARD TEMPERATURES BASED ON AN INVERSE SQUARE VARIATION OF GRAVITATIONAL FORCE — METRIC ENGINEERING SYSTEM — Concluded

Altitude, h (m)	Absolute tempera- ture, T (°K)	Pressure, P (kg/m ²)	Pressure ratio, P/P ₀	Density, ρ (kg-sec) ² m ⁻⁴	Density ratio, σ = P P ₀	Specific weight, γ = ρg (kg/m ³)	Coefficient of viscosity, μ (kg-sec) ² m ⁻¹	Kinematic viscosity, ν = μ γ (m ² /sec)	Speed of sound, U = $\sqrt{\gamma}$ (m/sec)	Mean free path of molecules, λ (m)
(b) For day only										
80,000	240.0	0.3675	3557×10^{-8}	5334×10^{-9}	4268×10^{-8}	5102×10^{-8}	1.568×10^{-6}	0.2940	310.6	1.68×10^{-3}
81,000	240.0	0.3201	3096	4508	3880	4395	1.568	0.3411	312.5	1.93
82,000	240.0	0.2793	2703	3970	3177	3765	1.568	0.3929	314.5	2.22
83,000	240.0	0.2439	2361	3432	2754	3260	1.568	0.4568	316.5	2.54
84,000	243.6	0.2136	2067	2931	2346	2800	1.568	0.5215	318.5	2.94
85,000	247.3	0.1877	1817	2613	2011	2309	1.567	0.5947	320.5	3.39
86,000	250.0	0.1653	1600	2150	1729	2062	1.567	0.6729	322.5	3.91
87,000	254.6	0.1462	1415	1864	1452	1779	1.566	0.8827	324.5	4.48
88,000	258.2	0.1297	1285	1614	1292	1540	1.566	1.031	326.5	5.12
89,000	261.9	0.1153	1176	1402	1122	1337	1.565	1.202	328.5	5.84
90,000	265.5	0.1029	995.6	1222	977.5	1165	1.704	1.396	327.1	6.64
91,000	269.2	0.09195	990.0	1067	853.00	1017	1.723	1.614	321.5	7.52
92,000	272.8	0.08244	797.9	925.1	748.0	801.0	1.742	1.862	320.5	8.50
93,000	276.5	0.07408	717.0	821.5	657.30	766.8	1.760	2.143	318.5	9.58
94,000	280.1	0.06666	615.7	723.6	579.0	660.5	1.779	2.434	316.5	10.6
95,000	283.8	0.06023	585.0	528.9	502.0	598.0	1.797	2.725	314.5	12.1
96,000	287.4	0.05453	527.8	509.8	452.00	478.0	1.814	3.016	312.5	13.5
97,000	291.1	0.04945	478.6	402.2	401.0	425.1	1.834	3.307	310.5	15.8
98,000	295.7	0.04494	432.0	446.3	357.0	426.5	1.852	3.598	308.5	18.7
99,000	299.4	0.04093	399.1	398.5	318.0	376.9	1.870	4.694	307.1	
100,000	302.0	0.03734	361.4	356.0	284.9	388.4	1.888	5.303	301.5	20.7
101,000	305.7	0.03412	330.2	321.4	232.6	305.5	1.906	6.028	299.5	23.4
102,000	309.3	0.03122	302.1	290.6	249.1	276.1	1.924	6.816	298.5	26.2
103,000	313.0	0.02859	276.7	263.1	210.5	249.3	1.941	7.375	296.5	29.9
104,000	315.6	0.02621	253.7	248.4	190.8	226.4	1.959	7.920	294.5	33.1
105,000	320.3	0.02406	233.8	216.3	173.1	205.3	1.976	8.429	292.5	36.5
106,000	323.9	0.02210	213.9	196.5	157.2	182.4	1.994	8.929	290.5	40.2
107,000	327.6	0.02032	196.7	176.7	143.0	160.5	2.011	9.424	288.5	44.3
108,000	331.2	0.01870	181.0	162.7	136.6	141.2	2.028	10.46	286.0	48.3
109,000	334.9	0.01723	166.8	148.2	118.6	140.5	2.045	13.79	284.3	49.7
110,000	338.5	0.01589	153.8	135.2	108.2	128.1	2.062	15.24	281.5	54.4
111,000	342.2	0.01465	147.9	123.5	98.79	117.0	2.079	16.83	279.5	58.6
112,000	345.8	0.01355	137.1	112.8	90.29	106.9	2.096	18.56	278.5	62.2
113,000	349.5	0.01252	121.2	103.2	82.66	97.75	2.113	20.45	276.5	71.2
114,000	353.1	0.01159	112.2	94.55	86.66	92.00	2.130	22.54	274.5	76.6
115,000	356.8	0.01074	103.9	96.27	80.34	94.46	2.146	24.75	272.5	84.8
116,000	360.4	0.009947	99.30	79.50	75.21	82.11	2.162	26.93	270.5	92.4
117,000	364.1	0.009227	89.30	73.00	58.41	75.03	2.179	28.83	268.5	101
118,000	367.7	0.008565	82.90	67.10	49.69	68.43	2.195	30.71	266.0	109
119,000	371.4	0.007958	77.02	61.72	45.36	55.33	2.211	32.62	264.1	119
120,000	375.0	0.007398	71.60	56.82	45.46	53.67	2.227	34.50	263.3	129
(c) For night only										
80,000	240.0	0.3675	3557×10^{-8}	5334×10^{-9}	4268×10^{-8}	5102×10^{-8}	1.568×10^{-6}	0.2940	310.6	1.68×10^{-3}
81,000	240.0	0.3196	3096	4641	3713	4395	1.568	0.3377	310.6	1.93
82,000	240.0	0.2784	2695	4041	3233	3863	1.568	0.3879	310.6	2.22
83,000	240.0	0.2424	2346	3518	2615	3361	1.568	0.4455	310.6	2.55
84,000	243.6	0.2112	2044	3020	2415	2885	1.568	0.5259	312.9	2.97
85,000	247.3	0.1844	1786	2598	2079	2481	1.607	0.6189	315.5	3.45
86,000	250.0	0.1613	1562	2240	1793	2138	1.627	0.7265	317.5	4.00
87,000	254.6	0.1415	1369	1936	1549	1847	1.645	0.8499	319.9	4.63
88,000	258.2	0.1243	1203	1675	1341	1599	1.666	0.9939	322.9	5.34
89,000	261.9	0.1094	1058	1455	1164	1387	1.685	1.155	324.4	6.16
90,000	265.5	0.09640	933.0	1265	1012	1206	1.704	1.347	326.7	7.08
91,000	269.2	0.08515	824.1	1101	881.1	1050	1.723	1.564	328.9	8.12
92,000	272.8	0.07533	729.1	961.8	769.6	916.4	1.742	1.811	331.4	9.31
93,000	276.5	0.06766	646.1	841.1	673.1	801.2	1.760	2.093	333.4	10.6
94,000	280.1	0.05926	573.5	737.0	589.7	701.8	1.779	2.414	335.5	12.1
95,000	283.8	0.05269	509.9	646.7	517.5	615.6	1.798	2.780	337.5	13.8
96,000	287.4	0.04691	445.0	568.3	454.9	541.1	1.816	3.195	339.9	15.7
97,000	291.1	0.04183	404.9	500.6	400.5	476.3	1.834	3.664	342.0	17.9
98,000	295.7	0.03736	348.0	441.5	353.3	420.0	1.852	4.196	344.2	20.3
99,000	299.4	0.03341	323.3	390.0	312.1	370.9	1.870	4.795	346.3	22.9
100,000	302.0	0.02992	285.5	345.0	276.1	328.0	1.888	5.472	348.4	25.9
101,000	305.7	0.02683	259.7	305.8	244.7	290.6	1.906	6.233	350.5	28.2
102,000	309.3	0.02409	233.2	271.3	217.1	257.8	1.924	7.090	352.6	30.3
103,000	313.0	0.02165	209.7	241.1	192.9	229.0	1.942	8.052	354.7	32.0
104,000	316.6	0.01950	188.8	214.5	171.6	203.7	1.959	9.130	356.7	34.6
105,000	320.3	0.01758	170.7	197.2	153.0	181.5	1.976	10.34	358.8	36.5
106,000	324.0	0.01588	153.7	168.4	134.8	159.8	1.994	11.84	360.9	38.2
107,000	327.6	0.01438	139.1	148.7	119.0	141.0	2.011	13.52	363.0	39.3
108,000	331.2	0.01305	126.3	131.7	105.4	124.8	2.028	15.41	369.0	40.3
109,000	334.9	0.01187	114.9	116.9	93.57	110.8	2.045	17.49	379.2	42.1
110,000	338.5	0.01082	104.8	104.1	83.30	98.63	2.062	19.81	384.3	49.9
111,000	342.2	0.009890	95.72	92.90	74.33	87.98	2.079	22.38	389.4	58.4
112,000	345.8	0.009059	87.68	83.11	66.50	78.70	2.096	24.96	394.5	57.5
113,000	349.5	0.008315	80.47	74.55	59.65	70.56	2.113	26.34	399.8	67.7
114,000	353.1	0.007546	74.00	66.99	53.60	63.40	2.130	27.76	404.9	118
115,000	356.8	0.007042	68.15	60.33	48.28	57.09	2.146	29.57	410.1	129
116,000	360.4	0.006499	62.90	54.44	43.56	51.49	2.162	30.72	415.3	141
117,000	364.1	0.006009	58.16	49.24	39.40	46.55	2.179	31.26	420.6	154
118,000	367.7	0.005567	53.88	44.63	35.71	42.18	2.195	31.98	425.8	168
119,000	371.4	0.005164	49.98	40.50	32.41	38.26	2.211	34.58	431.0	183
120,000	375.0	0.004800	45.45	36.86	29.50	34.82	2.227	36.32	436.3	199

¹ The values for viscosity listed in these columns are not applicable at the higher altitudes where the mean free paths of the molecules are comparable to or longer than the dimensions of the body being considered. Furthermore, the values listed are based on the conventional Sutherland formula for normal air and, consequently, no allowance has been made for the effect of dissociated oxygen in the atmosphere at the higher levels.

TABLE V.—PROPERTIES OF THE UPPER ATMOSPHERE FOR TENTATIVE STANDARD TEMPERATURES BASED ON AN
INVERSE SQUARE VARIATION OF GRAVITATIONAL FORCE—MAINTAIN ENGINEERING SYSTEM

Altitude, h (ft)	Absolute temperature, T (°F abs.)	Pressure, P (lb/in ²)	Pressure ratio, P/P ₀	Density, ρ (slugs/ft ³)	Density ratio, ρ/ρ ₀	Specific heat, C _p /C ₀ (lb-sec/ft ²)	Coefficient of viscosity, ν = C _p (lb-sec/ft ²)	Kinematic viscosity, ν = ρ (ft ² /sec)	Speed of sound, c (ft/sec)	Mean free path of molecules, λ (ft)
(a) For both day and night										
(b) For day										
65,000	392.4	119.9	266.4×10 ⁻³	1.779×10 ⁻⁷	748.9×10 ⁻⁵	2.961×10 ⁻⁷	0.001658	971.1	0.00322×10 ⁻³	
66,000	392.4	119.3	240.2	1618	6205	1.573	2.961	0.001745	971.1	0.00337
67,000	392.4	118.0	210.3	1543	6191	1.534	2.961	0.001830	971.1	0.00353
68,000	392.4	116.9	180.4	1471	6188	1.513	2.961	0.001919	971.1	0.00370
69,000	392.4	115.12	150.4			1.470	2.961	0.002013	971.1	0.00388
70,000	392.4	113.53	126.7	1403	5901	1.425	2.961	0.002110	971.1	0.00407
71,000	392.4	111.37	1063	1335	5829	1.377	2.961	0.002211	971.1	0.00427
72,000	392.4	109.36	878.7	1276	5768	1.329	2.961	0.002312	971.1	0.00446
73,000	392.4	107.00	707.5	1215	5708	1.280	2.961	0.002413	971.1	0.00465
74,000	392.4	104.74	557.2	1157	5658	1.229	2.961	0.002513	971.1	0.00482
75,000	392.4	102.54	427.1	1096	5608	1.177	2.961	0.002614	971.1	0.00501
76,000	392.4	99.47	305.6	1007	5434	1.125	2.961	0.002715	971.1	0.00519
77,000	392.4	96.47	205.6	956.0	5057	1.073	2.961	0.002816	971.1	0.00537
78,000	392.4	93.59	140.7	957	4954	1.021	2.961	0.002917	971.1	0.00554
79,000	392.4	91.69	91.9	935.7	4854	9.54	2.961	0.003018	971.1	0.00573
80,000	392.4	89.83	78.0	873.4	3673	2.89	2.961	0.003109	971.1	0.00592
81,000	392.4	87.10	62.1	824.7	3293	2.84	2.961	0.003198	971.1	0.00611
82,000	392.4	84.42	50.9	761.2	3140	2.79	2.961	0.003288	971.1	0.00630
83,000	392.4	81.82	41.67	727.6	3106	2.74	2.961	0.003378	971.1	0.00649
84,000	392.4	79.24	33.43	699.1	3039	2.69	2.961	0.003468	971.1	0.00668
85,000	392.4	76.74	26.43	657.7	2999	2.64	2.961	0.003558	971.1	0.00687
86,000	392.4	74.27	20.92	607	2951	2.59	2.961	0.003648	971.1	0.00706
87,000	392.4	71.81	16.15	557.6	2907	2.54	2.961	0.003738	971.1	0.00725
88,000	392.4	69.41	12.65	570.2	2859	2.49	2.961	0.003828	971.1	0.00744
89,000	392.4	67.01	9.13	513.0	2819	2.44	2.961	0.003918	971.1	0.00763
90,000	392.4	64.61	6.70	454.6	2786	2.39	2.961	0.004008	971.1	0.00782
91,000	392.4	62.22	4.38	405.9	2750	2.34	2.961	0.004098	971.1	0.00801
92,000	392.4	59.83	3.17	357.4	2715	2.29	2.961	0.004188	971.1	0.00820
93,000	392.4	57.43	2.17	312.1	2679	2.24	2.961	0.004278	971.1	0.00839
94,000	392.4	55.04	1.34	264.2	2642	2.19	2.961	0.004368	971.1	0.00858
95,000	392.4	52.65	0.67	219.5	2603	2.14	2.961	0.004458	971.1	0.00877
96,000	392.4	50.26	0.33	174.3	2563	2.09	2.961	0.004548	971.1	0.00896
97,000	392.4	47.87	0.17	139.3	2523	2.04	2.961	0.004638	971.1	0.00915
98,000	392.4	45.47	0.08	104.5	2483	1.99	2.961	0.004728	971.1	0.00934
99,000	392.4	43.08	0.04	71.9	2443	1.94	2.961	0.004818	971.1	0.00953
100,000	392.4	22.81	0.02	107.8	1924	1.89	1.879	0.005185	971.1	0.0105
102,000	392.4	29.75	0.01	860.9	1887	1.84	1.879	0.005056	971.1	0.00903
104,000	392.4	18.99	0.005	592.5	1851	1.79	1.879	0.005147	971.1	0.00813
106,000	392.4	10.27	0.002	327.7	1815	1.74	1.879	0.005237	971.1	0.00723
108,000	392.4	5.66	0.001	162.1	1780	1.69	1.879	0.005327	971.1	0.00632
110,000	392.4	3.16	0.0005	87.0	1745	1.64	1.879	0.005417	971.1	0.00541
112,000	392.4	1.86	0.0002	43.5	1720	1.59	1.879	0.005507	971.1	0.00450
114,000	392.4	1.03	0.0001	21.5	1695	1.54	1.879	0.005597	971.1	0.00359
116,000	392.4	0.52	0.00005	11.5	1670	1.49	1.879	0.005687	971.1	0.00268
118,000	392.4	0.26	0.00002	5.5	1645	1.44	1.879	0.005777	971.1	0.00177
120,000	452.8	9.111	0.001	140.0	503.7	1.39	1.879	0.006056	1152	0.0116
122,000	452.8	5.188	0.0005	86.5	452.2	1.34	1.879	0.006146	1152	0.0107
124,000	452.8	3.159	0.0002	47.7	401.8	1.29	1.879	0.006236	1152	0.0098
126,000	452.8	1.879	0.0001	24.5	351.4	1.24	1.879	0.006326	1152	0.0089
128,000	452.8	1.039	0.00005	12.5	301.0	1.19	1.879	0.006416	1152	0.0080
130,000	452.8	0.520	0.00002	6.5	250.6	1.14	1.879	0.006506	1152	0.0071
132,000	452.8	0.260	0.00001	3.5	200.2	1.09	1.879	0.006596	1152	0.0062
134,000	452.8	0.130	0.000005	1.5	159.8	1.04	1.879	0.006686	1152	0.0053
136,000	452.8	0.065	0.000002	0.5	119.4	0.99	1.879	0.006776	1152	0.0044
138,000	452.8	0.032	0.000001	0.2	79.0	0.94	1.879	0.006866	1152	0.0035
140,000	452.8	0.016	0.0000005	0.1	48.6	0.89	1.879	0.006956	1152	0.0026
142,000	452.8	0.008	0.0000002	0.05	28.2	0.84	1.879	0.007046	1152	0.0017
144,000	452.8	0.004	0.0000001	0.025	17.8	0.79	1.879	0.007136	1152	0.0008
146,000	452.8	0.002	0.00000005	0.0125	10.4	0.74	1.879	0.007226	1152	0.0003
148,000	452.8	0.001	0.00000002	0.00625	6.2	0.69	1.879	0.007316	1152	0.0001
150,000	452.8	0.0005	0.00000001	0.003125	3.1	0.64	1.879	0.007406	1152	0.00005
152,000	452.8	0.00025	0.000000005	0.0015625	1.6	0.59	1.879	0.007496	1152	0.000025
154,000	452.8	0.000125	0.0000000025	0.00078125	0.8	0.54	1.879	0.007586	1152	0.0000125
156,000	452.8	0.0000625	0.00000000125	0.000390625	0.4	0.49	1.879	0.007676	1152	0.00000625
158,000	452.8	0.00003125	0.000000000625	0.0001953125	0.2	0.44	1.879	0.007766	1152	0.000003125
160,000	452.8	0.000015625	0.0000000003125	0.00009765625	0.1	0.39	1.879	0.007856	1152	0.0000015625
162,000	452.8	0.0000078125	0.00000000015625	0.000048828125	0.05	0.34	1.879	0.007946	1152	0.00000078125
164,000	452.8	0.00000390625	0.000000000078125	0.0000244140625	0.025	0.29	1.879	0.008036	1152	0.000000390625
166,000	452.8	0.000001953125	0.0000000000390625	0.00001220703125	0.0125	0.24	1.879	0.008126	1152	0.0000001953125
168,000	452.8	0.0000009765625	0.00000000001953125	0.000006103515625	0.00625	0.2	1.879	0.008216	1152	0.00000009765625
170,000	452.8	0.00000048828125	0.000000000009765625	0.0000030517578125	0.003125	0.15	1.879	0.008306	1152	0.000000048828125
172,000	452.8	0.000000244140625	0.0000000000048828125	0.00000152587890625	0.0015625	0.075	1.879	0.008396	1152	0.0000000244140625
174,000	452.8	0.0000001220703125	0.00000000000152587890625	0.0000006123944944140625	0.00078125	0.0375	1.879	0.008486	1152	0.00000001220703125
176,000	452.8	0.00000006103515625	0.0000000000006123944944140625	0.00000030517578125	0.000390625	0.01875	1.879	0.008576	1152	0.00000006103515625
178,000	452.8	0.000000030517578125	0.00000000000030517578125	0.000000152587890625	0.0001953125	0.009375	1.879	0.008666	1152	0.000000030517578125
180,000	619.0	1.273	0.000000015625	0.000000000000015625	0.000000078125	0.00009375	1.879	0.008756	1220	0.0082
182,000	619.0	0.636	0.0000000078125	0.0000000000000078125	0.0000000390625	0.000046875	1.879	0.008846	1220	0.0083
184,000	619.0	0.318	0.00000000390625	0.00000000000000390625	0.00000001953125	0.0000234375	1.879	0.008936	1220	0.0084
186,000	619.0	0.159	0.000000001953125	0.000000000000001953125	0.000000009765625	0.00001171875	1.879	0.009026	1220	0.0085
188,000	619.0	0.074	0.0000000009765625	0.0000000000000009765625	0.0000000048828125	0.000005882	1.879	0.009116	1220	0.0086
190,000	619.0	0.0373	0.00000000048828125	0.00000000000000048828125	0.00000000244140625	0.00000294375	1.879	0.009206	1220	0.0087
192,000	619.0	0.0186	0.000000000244140625	0.000000000000000244140625	0.000000001220703125	0.000001471875	1.879	0.009296	1220	0.0088
194,000	619.0	0.0093	0.0000000001220703125	0.00000000000000012207031						

TABLE V -- PROPERTIES OF THE UPPER ATMOSPHERE FOR TENTATIVE STANDARD TEMPERATURES BASED ON AN
INVERSE SQUARE VARIATION OF GRAVITATIONAL FORCE -- BRITISH ENGINEERING SYSTEM -- Continued

Altitude, h (ft)	Absolute tempera- ture, T (°F abs.)	Pressure, P (lb/ft ²)	Pressure ratio, P/P ₀	Density, ρ (slugs/ft ³)	Density ratio, σ = P P ₀	Specific weight, γ = g ₀ (lb/ft ³)	Coefficient of viscosity, μ = P (lb-sec/ft ²) (1)	Kinematic viscosity, ν = μ (ft ² /sec) (1)	Speed of sound, a (ft/sec)	Mean free path of molecules, λ (ft)
(b) For day only										
262,467	432.0	0.07527	3.557×10 ⁻⁵	101.5×10 ⁻⁹	4.268×10 ⁻⁵	3.185×10 ⁻⁶	3.212×10 ⁻⁷	3.165	1019	5.53×10 ⁻³
264,000	432.0	0.07056	3.334	94.56	3.981	2.970	3.212	3.392	1022	5.90
266,000	432.0	0.06848	3.064	86.46	3.636	2.712	3.212	3.715	1026	6.42
268,000	432.0	0.05958	2.820	79.07	3.345	2.480	3.212	4.062	1030	6.97
270,000	432.0	0.05494	2.596	72.34	3.042	2.268	3.212	4.440	1034	7.57
272,000	432.0	0.05060	2.391	65.20	2.784	2.076	3.212	4.852	1038	8.22
272,309	432.0	0.04996	2.361	65.32	2.747	2.048	3.212	4.917	1038	8.32
274,000	435.4	0.04654	2.204	60.18	2.531	1.887	3.232	5.371	1046	8.98
276,000	439.4	0.04302	2.033	54.87	2.299	1.713	3.257	5.958	1054	9.82
278,000	433.4	0.03972	1.877	49.72	2.091	1.558	3.282	6.601	1063	10.7
280,000	447.4	0.03678	1.738	45.35	1.907	1.421	3.306	7.290	1072	11.7
282,000	451.4	0.03409	1.611	41.42	1.742	1.297	3.331	8.042	1081	12.7
284,000	455.4	0.03160	1.493	37.81	1.590	1.184	3.355	8.873	1082	13.9
286,000	459.4	0.02933	1.386	34.60	1.455	1.083	3.379	9.766	1098	15.1
288,000	463.4	0.02726	1.288	31.67	1.332	0.9915	3.403	10.75	1107	15.3
290,000	467.4	0.02537	1.199	29.06	1.222	0.9095	3.427	11.79	1116	17.7
292,000	471.4	0.02362	1.116	26.66	1.121	0.8342	3.451	12.94	1124	19.2
294,000	475.4	0.02201	1.040	24.49	1.030	0.7663	3.475	14.19	1133	20.7
296,000	479.4	0.02055	0.9710	22.55	0.9484	0.7054	3.499	15.52	1142	22.4
298,000	483.4	0.01919	0.9069	20.77	0.8734	0.6495	3.522	16.96	1151	24.2
300,000	487.4	0.01794	0.8479	19.15	0.8053	0.5988	3.546	18.52	1160	26.1
302,000	491.4	0.01679	0.7933	17.67	0.7430	0.5524	3.569	20.20	1168	28.1
304,000	495.4	0.01573	0.7435	16.33	0.6889	0.5105	3.592	22.00	1177	30.2
306,000	499.4	0.01475	0.6970	15.10	0.6352	0.4720	3.616	23.95	1186	32.5
308,000	503.4	0.01383	0.6537	13.97	0.5877	0.4366	3.639	26.05	1195	34.9
310,000	507.4	0.01299	0.6140	12.95	0.5446	0.4046	3.662	28.28	1204	37.4
312,000	511.5	0.01221	0.5772	12.01	0.5051	0.3751	3.685	30.68	1213	40.1
314,000	515.5	0.01149	0.5311	11.15	0.4690	0.3482	3.708	33.26	1222	43.0
316,000	519.5	0.01082	0.5114	10.37	0.4359	0.3236	3.731	36.98	1231	46.0
318,000	523.5	0.01020	0.4819	9.640	0.4054	0.3009	3.754	38.94	1240	49.2
320,000	527.5	0.009620	0.4546	8.977	0.3775	0.2802	3.777	42.07	1248	52.5
322,000	531.5	0.008779	0.4290	8.361	0.3516	0.2609	3.799	45.44	1257	56.1
324,000	535.5	0.008579	0.4054	7.800	0.3280	0.2424	3.822	49.00	1266	59.8
326,000	539.5	0.008103	0.3829	7.274	0.3059	0.2269	3.844	52.86	1275	63.7
328,000	543.5	0.007663	0.3621	6.791	0.2866	0.2118	3.867	56.94	1284	67.9
328,083	543.6	0.007548	0.3614	6.775	0.2849	0.2113	3.867	57.08	1285	68.0
330,000	547.5	0.007248	0.3425	6.375	0.2681	0.1968	3.889	61.00	1289	72.3
332,000	551.5	0.006867	0.3245	5.997	0.2522	0.1871	3.911	65.22	1294	75.8
334,000	555.5	0.006505	0.3074	5.640	0.2372	0.1758	3.933	69.73	1298	81.7
336,000	559.5	0.006167	0.2914	5.307	0.2232	0.1654	3.955	74.52	1303	86.8
338,000	563.5	0.005843	0.2761	4.994	0.2100	0.1556	3.977	79.64	1308	92.2
340,000	567.5	0.005540	0.2618	4.701	0.1977	0.1464	3.999	85.07	1312	97.9
342,000	571.5	0.005257	0.2484	4.430	0.1863	0.1379	4.021	90.77	1317	104
344,000	575.5	0.004992	0.2359	4.173	0.1757	0.1301	4.043	96.77	1322	110
346,000	579.5	0.004736	0.2238	3.935	0.1655	0.1226	4.065	103.3	1326	117
348,000	583.5	0.004499	0.2126	3.714	0.1562	0.1156	4.086	110.0	1331	124
350,000	587.5	0.004275	0.2020	3.505	0.1474	0.1091	4.108	117.2	1335	131
352,000	591.5	0.004061	0.1919	3.305	0.1390	0.1029	4.129	124.9	1340	139
354,000	595.5	0.003860	0.1824	3.122	0.1313	0.09716	4.151	133.0	1344	147
356,000	599.5	0.003672	0.1735	2.949	0.1240	0.09173	4.172	141.5	1349	156
358,000	603.5	0.003494	0.1651	2.787	0.1172	0.08668	4.193	150.4	1353	165
360,000	607.5	0.003329	0.1573	2.637	0.1110	0.08205	4.214	159.8	1358	174
362,000	611.5	0.003168	0.1497	2.494	0.1049	0.07758	4.236	169.8	1362	184
364,000	615.5	0.003016	0.1426	2.359	0.09922	0.07333	4.257	180.4	1367	195
366,000	619.5	0.002874	0.1358	2.234	0.08395	0.06942	4.278	191.5	1371	206
368,000	623.5	0.002738	0.1294	2.115	0.08894	0.06571	4.299	203.3	1376	217
370,000	627.5	0.002611	0.1234	2.004	0.08428	0.06225	4.319	215.6	1380	229
372,000	631.5	0.002489	0.1176	1.898	0.07981	0.05898	4.340	228.7	1384	242
374,000	635.5	0.002374	0.1126	1.799	0.07566	0.05586	4.361	242.4	1389	255
376,000	639.5	0.002266	0.1071	1.707	0.07177	0.05298	4.382	256.7	1393	269
378,000	643.5	0.002163	0.1022	1.618	0.06806	0.05023	4.402	272.1	1398	283
380,000	647.5	0.002054	0.09754	1.535	0.06456	0.04764	4.423	288.1	1402	299
382,000	651.5	0.001971	0.09316	1.457	0.06128	0.04522	4.443	304.9	1406	315
384,000	655.5	0.001884	0.08901	1.384	0.05819	0.04293	4.464	322.5	1411	331
386,000	659.5	0.001800	0.08505	1.314	0.05527	0.04076	4.484	341.2	1415	349
388,000	663.5	0.001721	0.08131	1.249	0.05252	0.03873	4.504	360.6	1419	367
390,000	667.5	0.001656	0.07776	1.187	0.04992	0.03681	4.525	381.2	1423	386
392,000	671.5	0.001573	0.07434	1.128	0.04744	0.03497	4.545	402.9	1428	406
393,700	675.0	0.001515	0.07160	1.081	0.04546	0.03350	4.562	422.0	1431	424

¹The values for viscosity listed in these columns are not applicable at the higher altitudes where the mean free paths of the molecules are comparable to or longer than the dimensions of the body being considered. Furthermore, the values listed are based on the conventional Sutherland formula for normal air and, consequently, no allowance has been made for the effect of dissociated oxygen in the atmosphere at the higher levels.

TABLE V.— PROPERTIES OF THE UPPER ATMOSPHERE FOR TENTATIVE STANDARD TEMPERATURES BASED ON AN
INVERSE SQUARE VARIATION OF GRAVITATIONAL FORCE— BRITISH ENGINEERING SYSTEM — Concluded

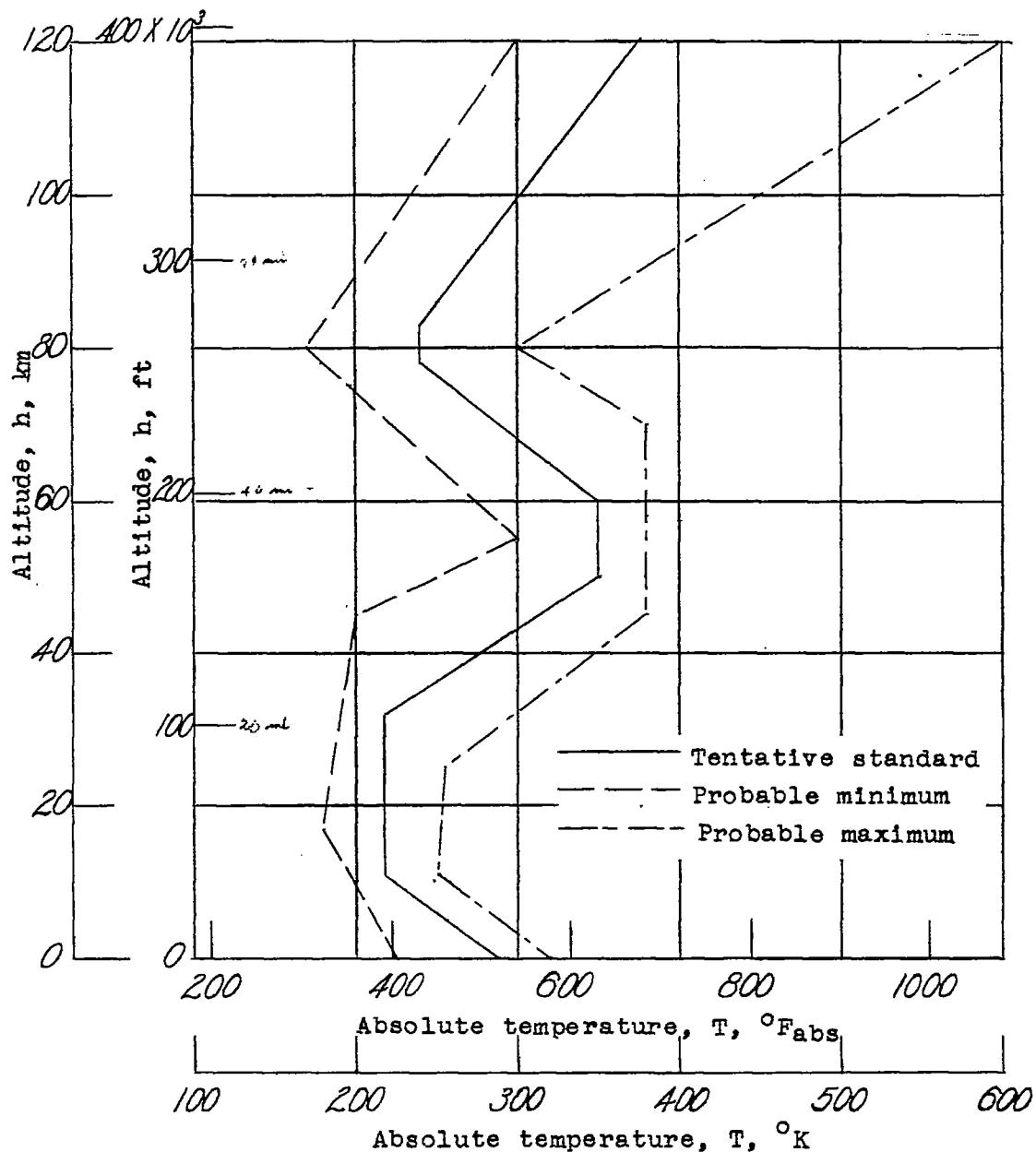
Altitude, h (ft)	Absolute tempera- ture, T (°F abs.)	Pressure, P (lb/ft ²)	Pressure ratio, P/P ₀	Density, ρ (slugs/ft ³)	Density ratio, ρ/ρ ₀	Specific weight, γ = ρg (lb/ft ³)	Coefficient of viscosity μ (lb·sec/ft ²) (1)	Kinematic viscosity, ν = μ/ρ (ft ² /sec) (1)	Speed of sound, a (ft/sec)	Mean free path of molecules, λ (ft)
(e) For night only										
262,467	432.0	0.07527	3.557×10 ⁻⁵	101.5×10 ⁻⁹	4.268×10 ⁻⁵	3.185×10 ⁻⁶	3.212×10 ⁻⁷	3.165	1019	5.53×10 ⁻³
264,000	432.0	0.07051	3.332	95.07	3.998	2.983	3.212	3.379	1019	5.28
266,000	432.0	0.06580	3.052	87.36	3.674	2.741	3.212	3.677	1019	5.03
268,000	432.0	0.06095	2.814	80.30	3.377	2.519	3.212	4.000	1019	4.82
270,000	432.0	0.05513	2.586	73.79	3.103	2.314	3.212	4.353	1019	4.60
272,000	432.0	0.05032	2.378	67.87	2.854	2.128	3.212	4.732	1019	4.26
272,309	432.0	0.04905	2.346	66.04	2.815	2.099	3.212	4.798	1019	4.31
274,000	435.4	0.04622	2.184	61.83	2.600	1.938	3.232	5.227	1023	9.06
276,000	439.4	0.04252	2.009	56.36	2.370	1.766	3.257	5.779	1028	9.94
278,000	443.4	0.03913	1.849	51.41	2.162	1.611	3.282	6.384	1032	10.9
280,000	447.4	0.03604	1.703	46.92	1.973	1.470	3.306	7.046	1037	11.9
282,000	451.4	0.03320	1.569	42.85	1.802	1.342	3.331	7.774	1042	13.1
284,000	455.4	0.03066	1.449	39.21	1.649	1.226	3.355	8.551	1046	14.3
286,000	459.4	0.02832	1.338	35.91	1.510	1.124	3.379	9.401	1051	15.6
288,000	463.4	0.02618	1.237	32.91	1.384	1.030	3.403	10.34	1055	17.0
290,000	467.4	0.02423	1.145	30.20	1.270	0.9452	3.427	11.35	1060	18.5
292,000	471.4	0.02239	1.058	27.65	1.163	0.8654	3.451	12.48	1064	20.2
294,000	475.4	0.02072	0.9793	25.40	1.068	0.7949	3.475	13.68	1069	22.0
296,000	479.4	0.01939	0.9069	23.32	0.9806	0.7294	3.499	15.00	1073	24.0
298,000	483.4	0.01780	0.8409	21.44	0.9017	0.6706	3.523	16.43	1078	26.1
300,000	487.4	0.01653	0.7810	19.75	0.8306	0.6176	3.546	17.95	1082	28.3
302,000	491.4	0.01534	0.7347	18.18	0.7645	0.5683	3.569	19.63	1087	30.8
304,000	495.4	0.01424	0.6729	16.74	0.7041	0.5233	3.593	21.46	1091	33.4
306,000	499.4	0.01324	0.6255	15.44	0.6492	0.4824	3.618	23.42	1096	36.2
308,000	503.4	0.01231	0.5818	14.25	0.5991	0.4451	3.639	25.54	1100	39.2
310,000	507.4	0.01165	0.5514	13.15	0.5531	0.4109	3.662	27.84	1104	42.4
312,000	511.5	0.01067	0.5042	12.15	0.5110	0.3799	3.685	30.33	1109	46.0
314,000	515.5	0.009940	0.4697	11.23	0.4724	0.3508	3.708	33.02	1113	49.7
316,000	519.5	0.009265	0.4378	10.39	0.4369	0.3244	3.731	35.91	1117	53.7
318,000	523.5	0.008643	0.4084	9.616	0.4044	0.3002	3.754	39.04	1122	58.0
320,000	527.5	0.008061	0.3809	8.903	0.3744	0.2779	3.777	42.42	1126	62.7
322,000	531.5	0.007527	0.3557	8.261	0.3470	0.2575	3.799	46.04	1130	67.6
324,000	535.5	0.007028	0.3321	7.645	0.3215	0.2385	3.822	49.99	1134	73.0
326,000	539.5	0.006571	0.3105	7.096	0.2984	0.2213	3.844	54.17	1139	78.6
328,000	543.5	0.006146	0.2904	6.587	0.2770	0.2054	3.867	58.71	1143	84.6
330,000	547.5	0.005750	0.2717	6.118	0.2573	0.1908	3.889	63.57	1147	91.1
332,000	551.5	0.005379	0.2542	5.681	0.2389	0.1771	3.911	68.84	1151	98.1
334,000	555.5	0.005039	0.2381	5.284	0.2222	0.1647	3.933	74.43	1155	105
336,000	559.5	0.004721	0.2231	4.915	0.2067	0.1532	3.955	80.47	1160	113
338,000	563.5	0.004427	0.2092	4.577	0.1925	0.1426	3.977	86.91	1164	122
340,000	567.5	0.004152	0.1962	4.261	0.1792	0.1327	3.999	93.85	1168	131
342,000	571.5	0.003892	0.1839	3.966	0.1668	0.1235	4.021	101.4	1172	140
344,000	575.5	0.003655	0.1727	3.700	0.1556	0.1152	4.043	109.3	1176	150
344,487	576.5	0.003602	0.1702	3.638	0.1530	0.1134	4.048	111.2	1177	153
346,000	579.5	0.003433	0.1623	3.429	0.1442	0.1058	4.065	118.5	1185	161
348,000	583.5	0.003231	0.1587	3.179	0.1337	0.09896	4.108	139.5	1205	184
350,000	587.5	0.003041	0.1437	2.946	0.1239	0.09269	4.129	151.1	1215	197
352,000	591.5	0.002863	0.1353	2.732	0.1149	0.08502	4.151	163.6	1226	211
354,000	595.5	0.002700	0.1276	2.537	0.1067	0.07893	4.172	176.9	1236	225
356,000	599.5	0.002546	0.1203	2.358	0.09916	0.07334	4.193	191.1	1246	240
358,000	603.5	0.002404	0.1136	2.194	0.09227	0.06823	4.193	206.2	1256	255
360,000	607.5	0.002273	0.1074	2.044	0.08597	0.06356	4.214	222.2	1266	271
362,000	611.2	0.002150	0.1016	1.906	0.08015	0.05925	4.236	239.4	1277	286
364,000	615.2	0.002038	0.09614	1.778	0.07476	0.05525	4.257	257.6	1287	306
366,000	619.0	0.001928	0.09111	1.651	0.06984	0.05161	4.278	276.8	1297	325
368,000	623.6	0.001828	0.08659	1.523	0.06529	0.04824	4.299	297.2	1308	345
370,000	627.6	0.001736	0.08201	1.453	0.06111	0.04514	4.319	318.9	1318	365
372,000	631.6	0.001649	0.07790	1.361	0.05724	0.04227	4.340	341.8	1328	386
374,000	635.6	0.001567	0.07405	1.276	0.05386	0.03962	4.361	366.1	1339	409
376,000	639.6	0.001489	0.07038	1.197	0.05033	0.03716	4.382	392.0	1349	433
378,000	643.6	0.001417	0.06698	1.123	0.04722	0.03485	4.402	419.2	1360	457
380,000	647.6	0.001350	0.06379	1.055	0.04436	0.03274	4.423	448.0	1370	482
382,000	651.6	0.001286	0.06079	0.9916	0.04170	0.03077	4.443	478.4	1381	509
384,000	655.6	0.001227	0.05797	0.9331	0.03924	0.02895	4.464	510.5	1391	536
386,000	659.6	0.001170	0.05531	0.8784	0.03694	0.02725	4.484	544.2	1401	565
388,000	663.6	0.001118	0.05282	0.8277	0.03481	0.02567	4.504	579.8	1412	595
390,000	667.6	0.001068	0.05045	0.7804	0.03282	0.02420	4.525	617.2	1422	626
392,000	671.6	0.001020	0.04823	0.7364	0.03097	0.02282	4.545	650.4	1431	653
393,700	675.0	0.0009830	0.04645	0.7015	0.02950	0.02173	4.562	682.0		

¹The values for viscosity listed in these columns are not applicable at the higher altitudes where the mean free paths of the molecules are comparable to or longer than the dimensions of the body being considered. Furthermore, the values listed are based on the conventional Sutherland formula for normal air and, consequently, no allowance has been made for the effect of dissociated oxygen in the atmosphere at the higher levels.

TABLE VI.— LATITUDE CORRECTION FACTORS FOR VALUES OF PRESSURE IN TABLES IV AND V

Latitude, deg		0	10	20	30	40	50	60	70	80	90
Altitude, h (km)	(ft)										
(a) For both day and night											
20	65,617	1.0078	1.0073	1.0060	1.0039	1.0014	0.9988	0.9963	0.9943	0.9929	0.9925
30	98,425	1.0120	1.0112	1.0092	1.0060	1.0022	.9981	.9943	.9912	.9892	.9885
40	131,233	1.0158	1.0148	1.0121	1.0080	1.0029	.9975	.9925	.9884	.9858	.9848
50	164,042	1.0187	1.0176	1.0144	1.0094	1.0034	.9971	.9911	.9863	.9832	.9821
60	196,850	1.0213	1.0200	1.0164	1.0108	1.0039	.9967	.9899	.9844	.9808	.9796
70	229,658	1.0242	1.0227	1.0186	1.0122	1.0044	.9962	.9866	.9824	.9783	.9769
80	262,467	1.0278	1.0260	1.0212	1.0140	1.0051	.9957	.9869	.9798	.9752	.9736
(b) For day only											
80	262,467	1.0278	1.0260	1.0212	1.0140	1.0051	0.9957	0.9869	0.9798	0.9752	0.9736
90	295,275	1.0312	1.0293	1.0239	1.0157	1.0057	.9952	.9853	.9774	.9722	.9704
100	328,083	1.0340	1.0319	1.0261	1.0171	1.0062	.9947	.9840	.9754	.9698	.9679
110	360,892	1.0364	1.0342	1.0279	1.0183	1.0066	.9944	.9830	.9738	.9678	.9657
120	393,700	1.0385	1.0361	1.0295	1.0193	1.0070	.9940	.9820	.9723	.9660	.9638
(c) For night only											
80	262,467	1.0278	1.0260	1.0212	1.0140	1.0051	0.9957	0.9869	0.9798	0.9752	0.9736
90	295,275	1.0314	1.0295	1.0241	1.0158	1.0057	.9951	.9852	.9772	.9721	.9703
100	328,083	1.0346	1.0325	1.0265	1.0174	1.0063	.9946	.9838	.9750	.9693	.9673
110	360,892	1.0374	1.0352	1.0287	1.0188	1.0068	.9942	.9825	.9730	.9669	.9647
120	393,700	1.0397	1.0373	1.0304	1.0199	1.0072	.9938	.9815	.9714	.9649	.9627

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Figure 1.- Variation of ambient temperature with altitude.

FIG. 2

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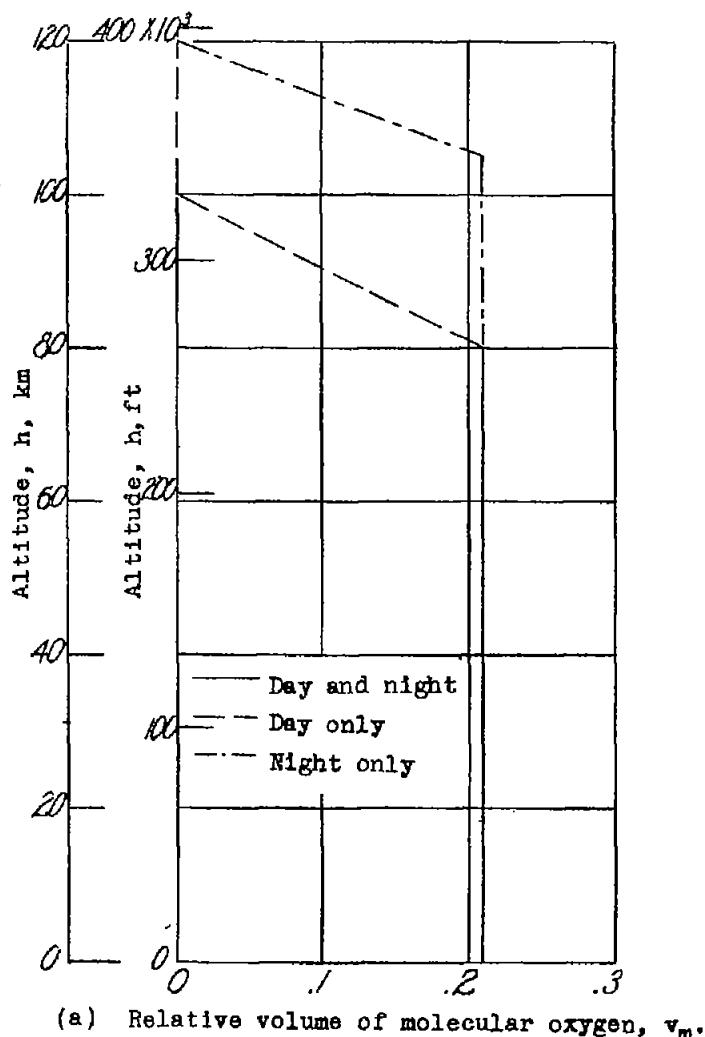
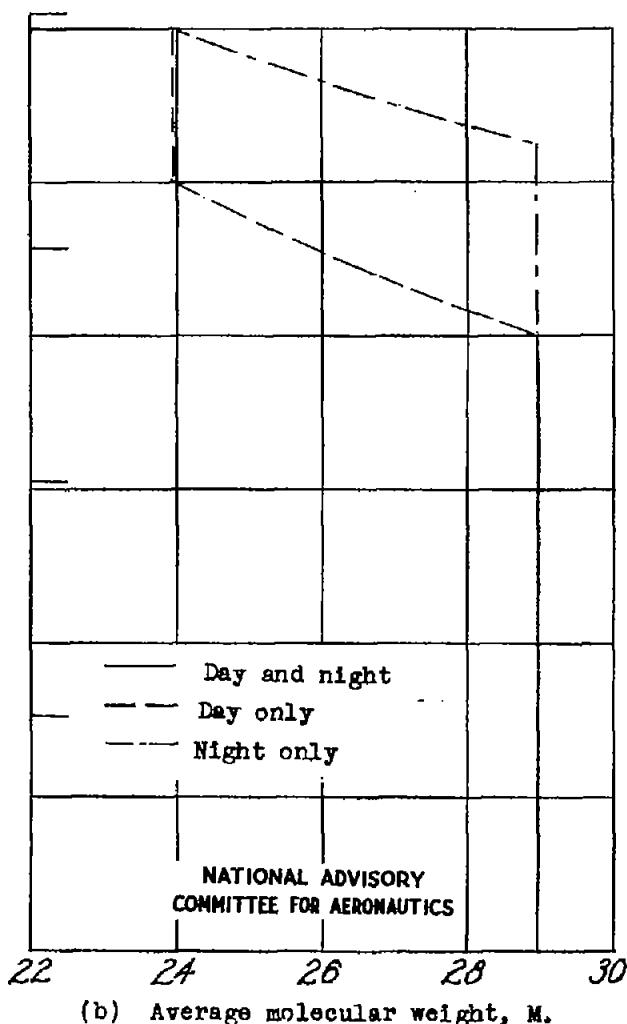
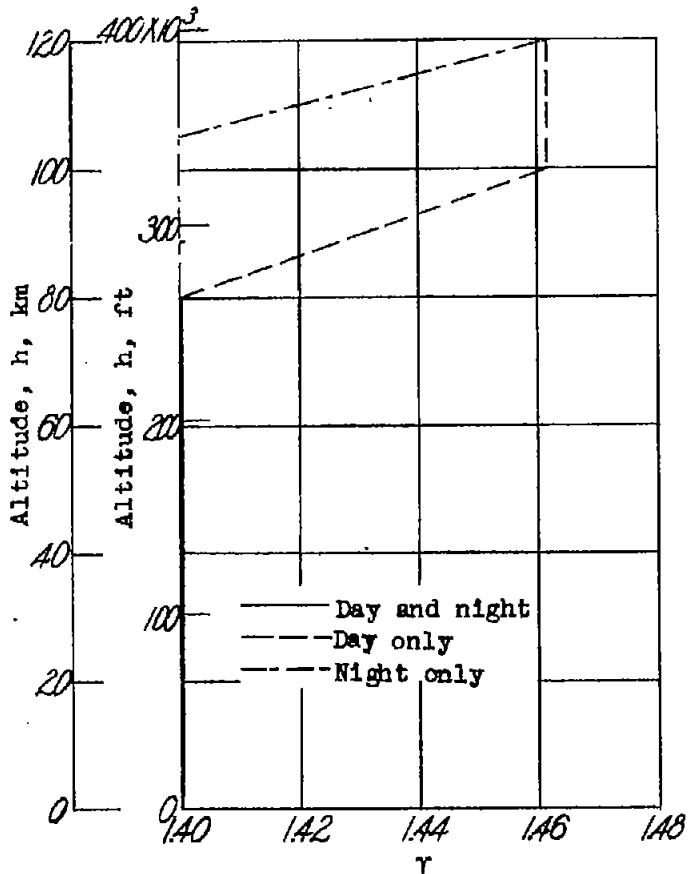
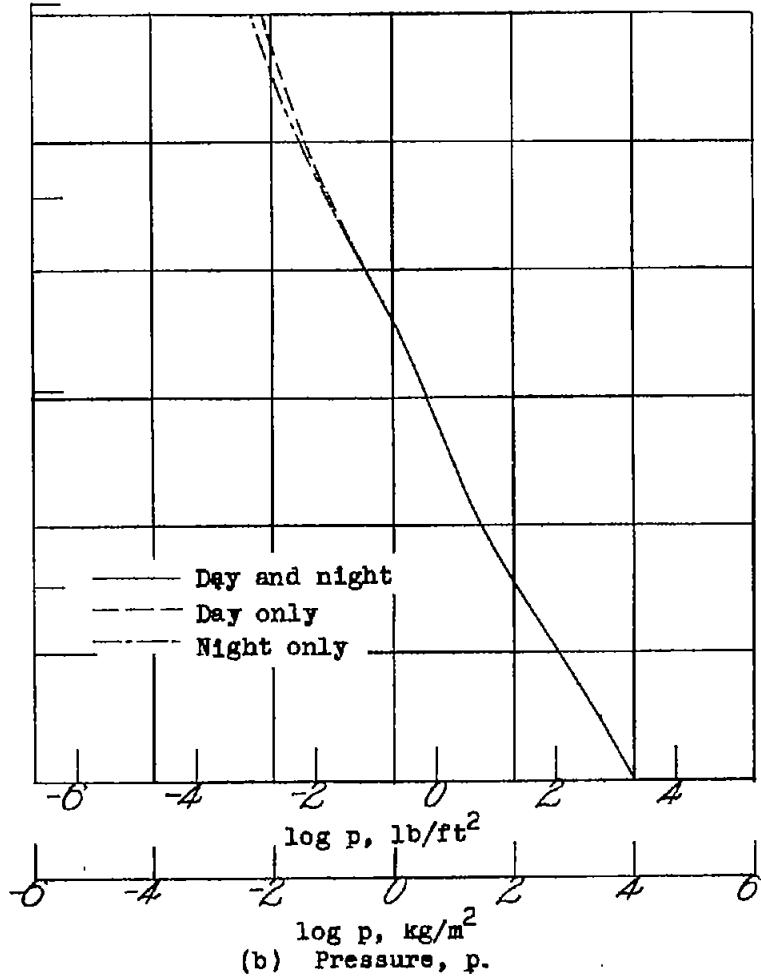
(a) Relative volume of molecular oxygen, v_m .(b) Average molecular weight, M .

Figure 2.- Variation of composition of the tentative standard atmosphere with altitude. (The dissociation of oxygen is the only change in composition occurring in the tentative standard atmosphere.)



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(a) Ratio of specific heats, γ .



(b) Pressure, p .

Figure 3. Variation with altitude of the physical properties of the tentative standard atmosphere.

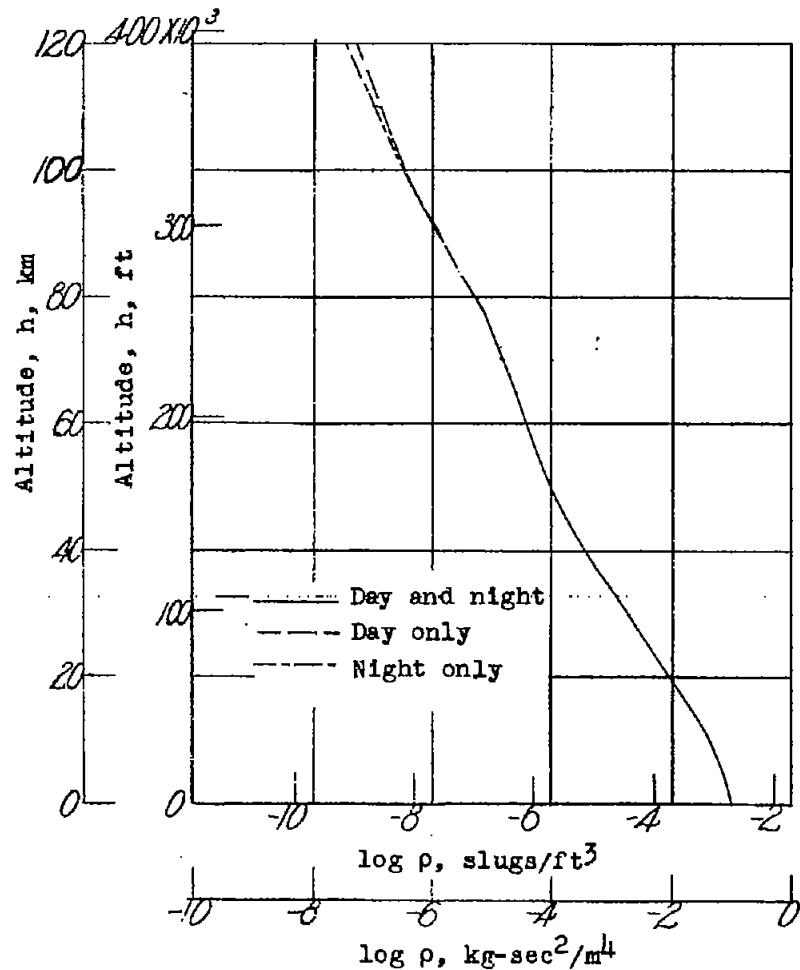
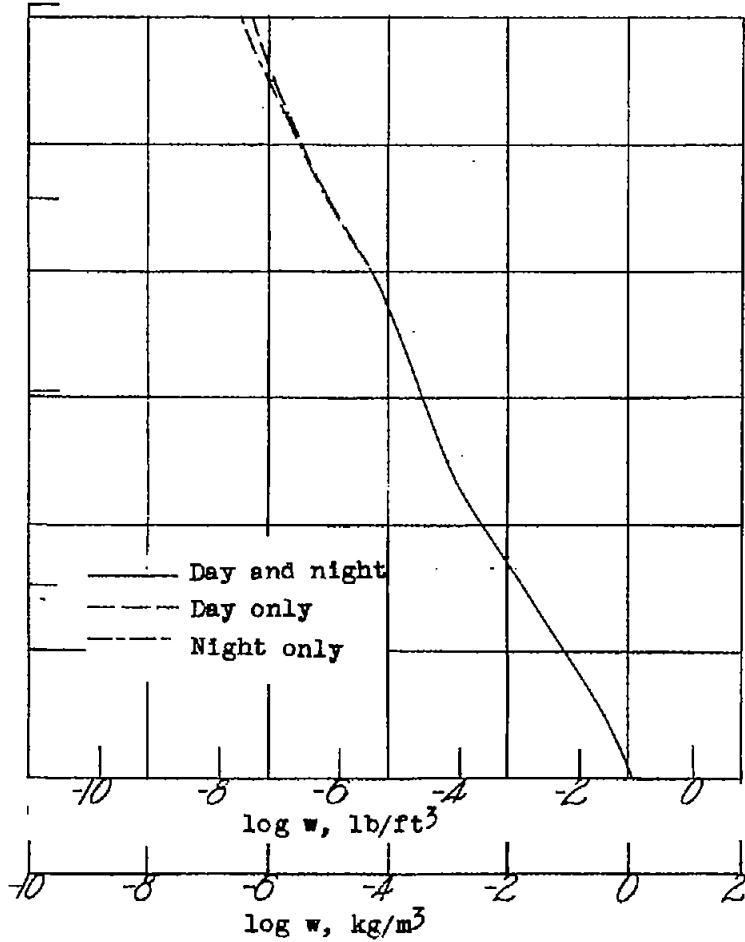
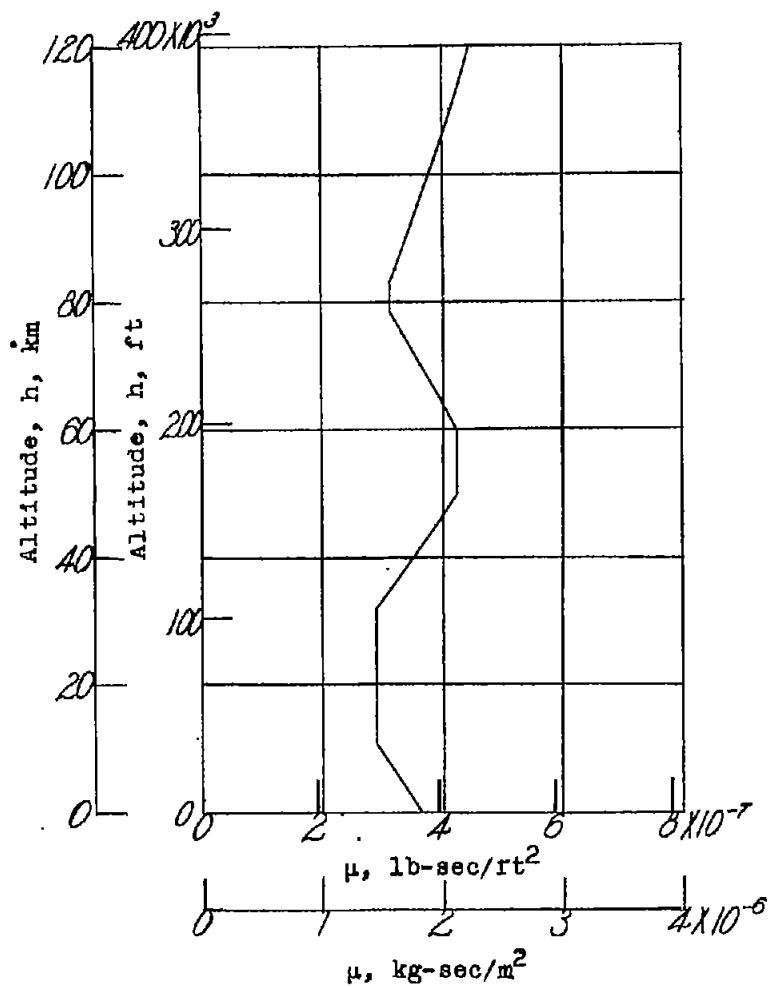
(c) Density, ρ .(d) Specific weight, w .

Figure 3.- Continued.

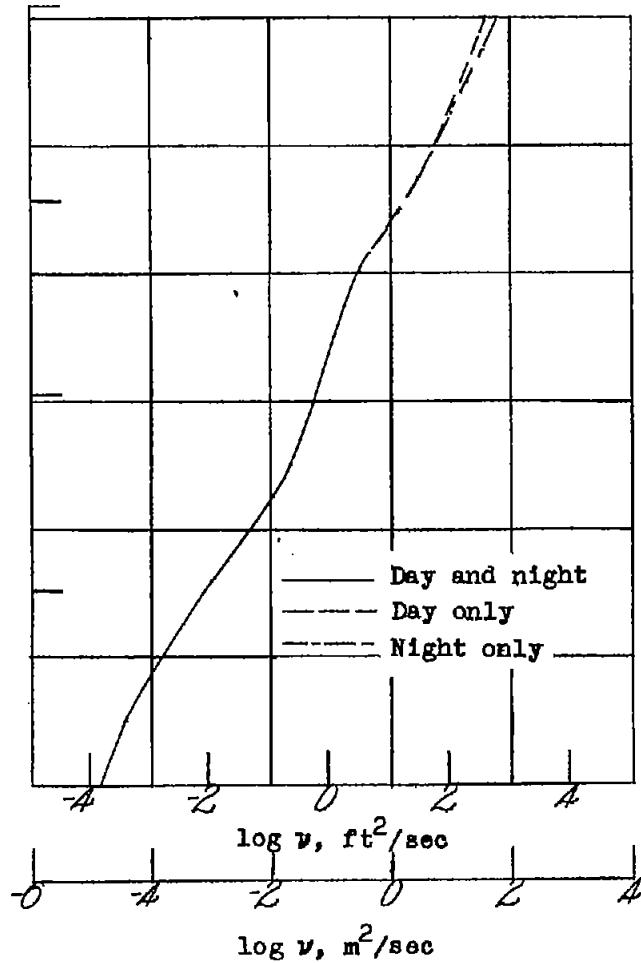
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(e) Coefficient of viscosity, μ .

Figure 3.- Continued.

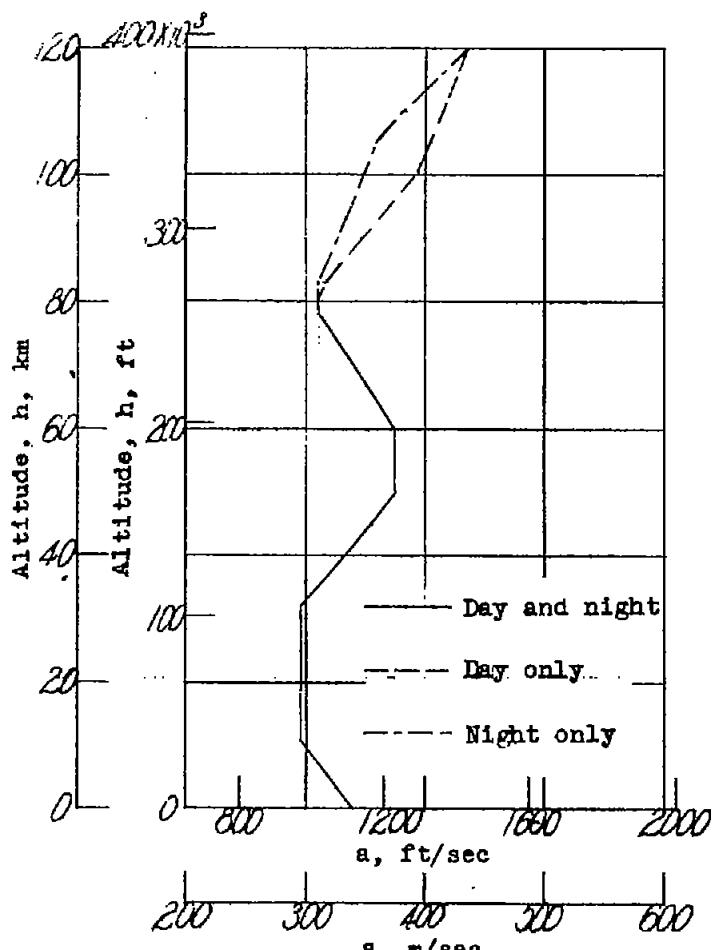
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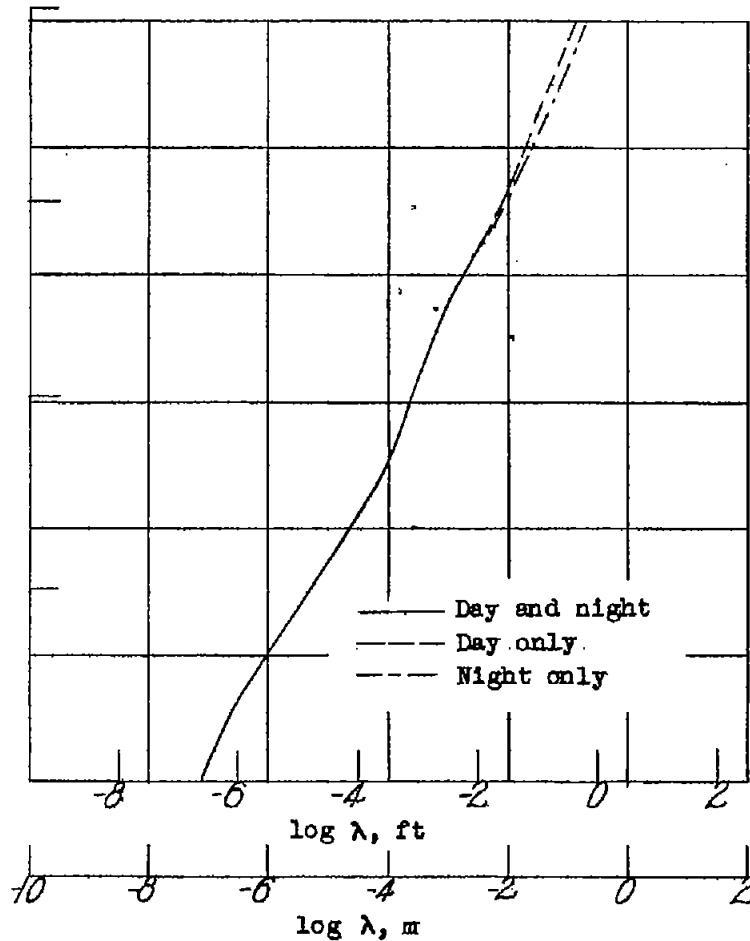
(f) Kinematic viscosity, ν .

FIG. 3g,h

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(g) Speed of sound, a .



(h) Mean free path of molecules, λ .

Figure 3.- Concluded.

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